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TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 2 AUGUST 1991

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WORK PLAN

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FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

AUGUST 1991

U.S. DEPARTMENT OF ENERGY
FERNALD SITE OFFICE

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LIST OF ACRONYMS

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ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society of Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Protocol
DAC	derived air concentrations
DOE	U.S. Department of Energy
DQO	data quality objective
ECP	Emergency Contingency Plan
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
ETDC	Environmental Technology Development Center
FFCA	Federal Facilities Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
H&S	health and safety
HSL	Hazardous Substances List
HSP	Health and Safety Plan
INEL	Idaho National Engineering Laboratory
ISA	Initial Screening of Alternatives
IT	International Technology Corporation
MCL	maximum contaminant level
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PCSS	portland cement/soluble silicate
psi	pounds per square inch
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
QCC	quality control coordinator
RAO	remedial action objective
RCRA	Resource Conservation Recovery Act
RfD	reference dose
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	record of decision
SAP	Sampling and Analysis Plan

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SARA	Superfund Amendments and Reauthorization Act
SSM	shallow soil mixing
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
UCS	unconfined compressive strength
WEMCO	Westinghouse Environmental Management Company of Ohio
WERF	Waste Experimental Reduction Facility

DISTRIBUTION LIST

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1.0 PROJECT DESCRIPTION

Under Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the U.S. Environmental Protection Agency (EPA) is required to evaluate remedial actions that "permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants." To this end, treatability studies provide valuable site-specific data necessary to support CERCLA remedial activities when treatment is proposed as part of one or more remedial alternatives. Treatability studies serve two primary purposes: (1) to aid in the selection of the remedy, and (2) to aid in the implementation of the selected remedy. Therefore, this work plan proposes treatability studies to support the remedial investigation/feasibility study (RI/FS) for Operable Unit 2 at the Feed Materials Production Center (FMPC) near Fernald, Ohio.

The FMPC is a contractor-operated federal facility which has historically been used for the production of pure uranium for the U.S. Department of Energy (DOE). The FMPC is located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati. On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by the EPA and DOE to ensure that impacts associated with past and present activities at the FMPC are thoroughly investigated so that appropriate remedial actions can be assessed and implemented. The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of CERCLA (Consent Agreement) in order to achieve consistency with the operable unit concept and the current commitments of the RI/FS program without modifying the underlying objectives. The Consent Agreement was signed on April 9, 1990, and became effective on June 29, 1990.

In response to the FFCA and the Consent Agreement, DOE is conducting an RI/FS pursuant to CERCLA/SARA. The technical strategy adopted for the RI/FS is to issue distinct RI/FS reports for each of the five identified operable units at the FMPC.

Operable Unit 2 encompasses the Sanitary Landfill, the Lime Sludge Ponds, the Active and Inactive Fly Ash Disposal areas, and the Southfield. A report on the development of remedial alternatives can be found in the final "Initial Screening of Alternatives for Operable Unit 2" (ISA) report of April 1991 (DOE 1991). Waste treatment technologies identified for Operable Unit 2 wastes include cement-based solidification for the Lime Sludge Ponds and Fly Ash/Southfield areas and for the residuals from rotary kiln incineration of Sanitary Landfill wastes (which could contain radionuclides not eliminated by incineration).

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1.1 PURPOSE OF TREATABILITY STUDY

The purpose of this study is to provide additional information to support the feasibility study (FS) and subsequent remedy selection for Operable Unit 2. Specifically, the study will demonstrate whether solidification can achieve a desired level of material strength, as well as obtain quantitative data for geochemical modeling and subsequent computer modeling of groundwater contaminant transport. The results of the contaminant transport modeling will be used to quantitatively assess the relative effectiveness of the removal and nonremoval alternatives that are being evaluated. These comparisons (which will be performed in the detailed analysis of alternatives) will include an analysis to determine whether applicable or relevant and appropriate requirements (ARARs) for groundwater are being met for each of the various alternatives being studied.

The study is composed of two parts: preliminary stages (to support remedy screening) and advanced stages (to support remedy selection). The preliminary stage involves evaluating a range of solidification mix formulations in order to determine a representative formulation which meets the proposed strength criteria. The advanced stage study involves performing toxicity characteristic leaching procedure (TCLP) leach tests on solidified waste using representative formulations determined in the preliminary stage. The data resulting from this treatability study will be used to support the FS through comparison of leachate test results from the advanced stage testing with leaching results from tests performed on representative samples of unsolidified Operable Unit 2 wastes. The unsolidified waste testing will be performed under a separate program. The data resulting from the two-part treatability study will also be used to support the FS by establishing or identifying the following:

- Confirmation of technology applicability to Operable Unit 2 waste
- Compliance of technology with ARARs
- Analytical results to be used for fate and transport modeling
- Leachability data to support residual risk calculations in support of the effectiveness criteria evaluation for the detailed analysis of alternatives
- Refinement of process requirements for cost estimation purposes
- Initial database for use in subsequent remedy design studies

In some instances it is appropriate to distinguish between solidification (techniques used to encapsulate waste within a monolithic solid of high structural integrity) and stabilization (techniques used to reduce solubility, mobility, and toxicity). However, for purposes of this work plan, the two terms will be used interchangeably.

1.2 SITE DESCRIPTION

The following subsections contain a brief summary of site characterization information for Operable Unit 2 based on data available at this time. Additional sampling and analytical testing of Operable Unit 2 waste areas are currently being conducted in support of site characterization. Figure 1-1 depicts the location of Operable Unit 2 waste disposal areas and monitoring wells within the FMPC property. Chemicals of potential concern for Operable Unit 2 (previously identified during the development of preliminary documents, based on limited characterization) are listed in Table 1-1.

1.2.1 Sanitary Landfill

The Sanitary Landfill was used for the disposal of cafeteria waste, rubbish, and other types of wastes from nonproduction areas. Materials reported to have been disposed of in the past include, but are not limited to, nonburnable and nonradioactive sanitary wastes generated on property, nonradioactive construction rubble placed in the landfill, and the soil that was used to cover exposed wastes that may have been contaminated with radionuclides. The five existing cells, when filled to capacity, were covered with soil. Use of the landfill was halted in early 1986.

The Sanitary Landfill contains the highest diversity of organic and inorganic chemicals among the Operable Unit 2 sites. A large variety of organic compounds, including polychlorinated biphenyls (PCBs) (e.g., aroclors 1242, 1248, and 1254), polynuclear aromatic hydrocarbons (e.g., benzo[a]pyrene and benzo[b]fluoranthene), other volatile organics (e.g., 1,1,1-trichloroethane and benzene), semivolatile organics (e.g., naphthalene and phenol), and common laboratory contaminants (e.g., acetone, methylene chloride, and di-n-butyl phthalate) were all detected in samples of waste from the landfill. In addition to the organic compounds, the following were detected at concentrations above available background levels: cadmium, zinc, uranium-234, U-235, and U-238. Ranges of detected values of contaminants in the Sanitary Landfill waste are presented in Table B-1 of Appendix B.

Chemicals detected above blank and background concentrations in both the source and perched groundwater were cadmium, U-234, and U-238. Wells 1035 and 1038 are screened in the perched groundwater beneath the Sanitary Landfill. Well 1035 is located north of the landfill, and Well 1038 is located south of the landfill. The concentrations of cadmium ranged from 0.007 to 0.0128 ppm. The highest concentration of cadmium was detected in Well 1038. U-234 and U-238 detected in the perched groundwater beneath the Sanitary Landfill ranged from 1.2 ± 0.4 picocuries per liter (pCi/ℓ) to 4.6 ± 0.7 pCi/ℓ and from 1.0 ± 0.3 pCi/ℓ to 3.9 ± 0.6 pCi/ℓ, respectively.

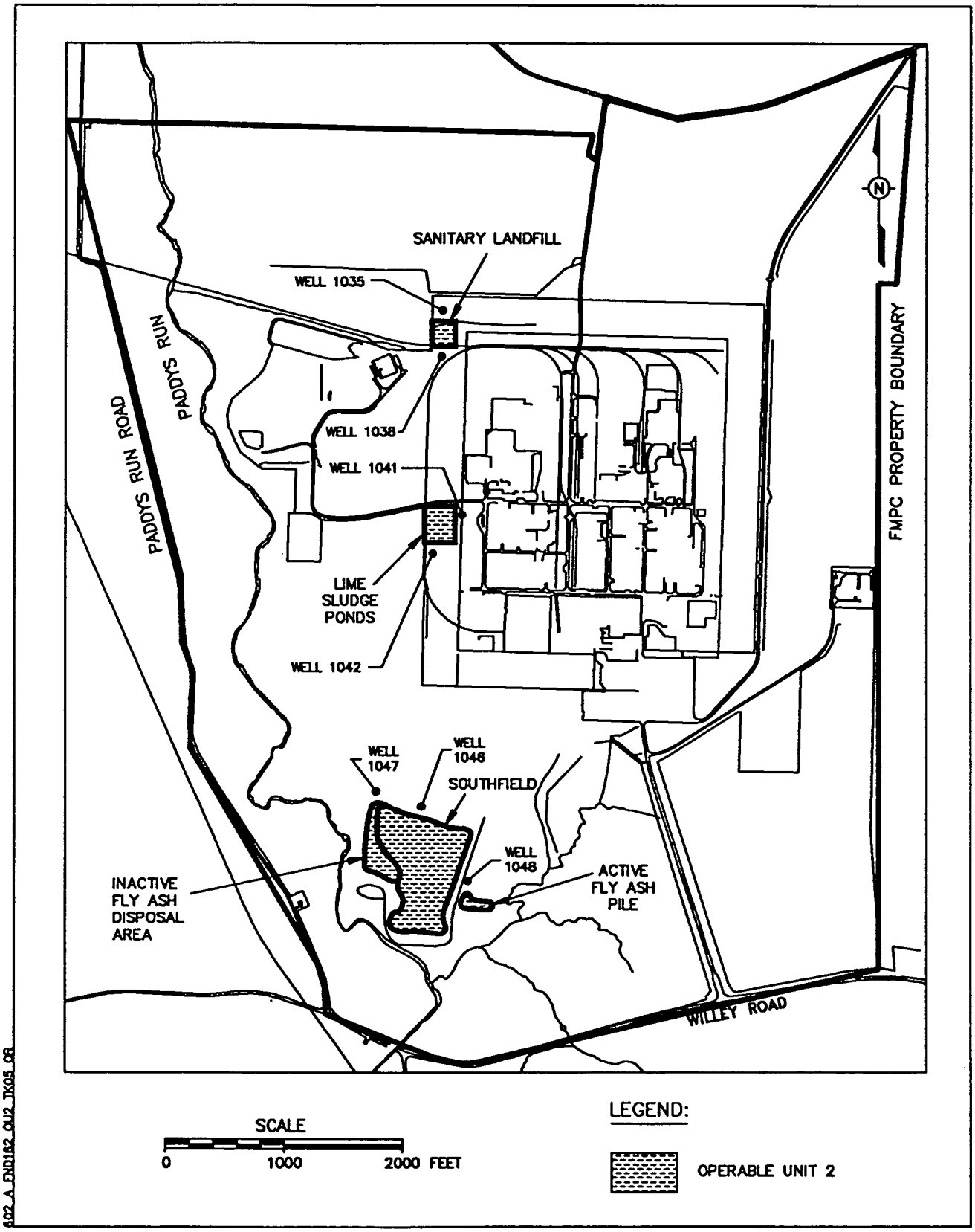

FIGURE 1-1. OPERABLE UNIT 2 SITE PLAN

TABLE 1-1
CHEMICALS AND RADIONUCLIDES OF POTENTIAL CURRENT CONCERN FOR OPERABLE UNIT 2

Sanitary Landfill	Lime Sludge Ponds	Inactive Fly Ash Disposal Area	Active Fly Ash Pile	Southfield
Bis(2-ethyl)hexyl phthalate	Acetone	Lead	Acetone	Cadmium
Di-n-butyl phthalate	Uranium	Uranium	Methylene chloride	Mercury
Cadmium	Thorium-230	Radium-226	Lead	Uranium
Uranium	Thorium-232	Radium-228	Uranium	Radium-226
Zinc	Uranium-234	Uranium-234	Radium-228	Radium-228
Uranium-234	Uranium-238	Uranium-238	Uranium-234	Uranium-234
Uranium-238			Uranium-235	Uranium-235
			Uranium-238	Uranium-238

1.2.2 Lime Sludge Ponds

Spent lime sludges from FMPC water treatment plant operations (lime alum sludges and boiler plant blowdown) were pumped to these ponds and allowed to settle. Organic compounds (maximum detected concentrations denoted parenthetically) detected in both the North and South Lime Sludge Ponds include: phenol (61 µg/kg), acetone (140 µg/kg), bis(2-ethylhexyl)phthalate (310 µg/kg), di-n-butyl phthalate (330 µg/kg), and methylene chloride (240 µg/kg). Detection of these chemicals may be attributed to laboratory contamination. Inorganic chemicals and radionuclides detected at concentrations greater than background levels in the lime sludge were thorium-230 (20 pCi/g), U-234 (3.1 pCi/g), U-235 (0.3 pCi/g), U-238 (7.6 pCi/g), and strontium-90 (2.2 pCi/g) (North Pond only). Ranges of concentrations are contained in Table B-2 of Appendix B.

Radionuclides detected at concentrations above background levels in both the Lime Sludge Ponds and perched groundwater were Th-230, U-234, and U-238. In the Lime Sludge Ponds, the background level for Th-230 is 1.5 pCi/g; for U-234 and U-238 it is 1.4 pCi/g. In the perched groundwater the background level is 1.0 pCi/ℓ for these same radionuclides. U-234 and U-238 detected in the perched groundwater beneath the Lime Sludge Ponds ranged from 1.4 ± 0.4 pCi/ℓ to 9.5 ± 1.5 pCi/ℓ and from 1.7 ± 0.5 pCi/ℓ to 9.7 ± 1.5 pCi/ℓ, respectively. The highest concentration of U-234 and U-238 were measured in Well 1042, located southwest of the Lime Sludge Ponds. The highest concentration of Th-230, 1.6 ± 0.6 pCi/ℓ, was measured in Well 1041, located in the east berm of the South Pond.

Organics detected in the Lime Sludge Ponds were not detected in perched groundwater beneath the ponds. This suggests that these organics have been contained within the Lime Sludge Ponds or bound in the surrounding glacial overburden.

1.2.3 Active Fly Ash Pile

This waste disposal area has received fly ash resulting from the combustion of coal as part of the FMPC boiler plant operations. Fly ash from the mechanical and electrostatic precipitators is combined with bottom ash and hauled to the Active Fly Ash Pile. Chemical analyses of constituents in the Active Fly Ash Pile were performed for barium and chromium (identified as hazardous metals by the Resource Conservation and Recovery Act [RCRA]), volatile organics, and radionuclides in composited and surface soil samples. Analyses for inorganic and PCB constituents will be performed on additional samples collected. Organics detected in the Active Fly Ash Pile were acetone (940 µg/kg), 2-butanone (67 µg/kg), chloroform (11 µg/kg), methylene chloride (1100 µg/kg), 1,1,1-tricholoroethane (420 µg/kg), and toluene (89 µg/kg). Acetone and methylene chloride are common laboratory contaminants. In addition to these constituents, lead (Pb)-210, Ra-226, Th-228, Th-230, U-234, U-235, and U-238 were detected at above background levels in the Active Fly Ash Pile. Ranges of concentrations are contained in Table B-3 of Appendix B. Neither inorganic nor PCB analyses were performed on samples taken in the Active Fly Ash Pile. Concentrations of these constituents were

assumed to be similar to those in the Inactive Fly Ash Disposal Area. The only inorganic chemicals detected at above-background concentrations in the Inactive Fly Ash Disposal Area were cadmium and lead. The mean background levels for cadmium and lead are 1.7 mg/kg and 17 mg/kg, respectively.

Metals, including radionuclides, detected at concentrations above background levels in both the Active Fly Ash Pile and the perched groundwater underneath it were U-234, U-238, and cadmium. U-234 and U-238 detected in the perched groundwater ranged from 4.5 ± 1.0 pCi/ℓ to 6.6 ± 1.2 pCi/ℓ and from 4.0 ± 1.0 pCi/ℓ to 6.9 ± 1.1 pCi/ℓ, respectively. U-234 and U-238 were detected in Well 1048, located north of the Active Fly Ash Pile. Cadmium was detected at a concentration of 0.0069 mg/ℓ in Well 1048.

1.2.4 Inactive Fly Ash Disposal Area

This disposal area also received fly ash from the FMPC boiler plant from 1951 to the mid 1960's. Comparison of both chemicals and radionuclides in the Inactive Fly Ash Disposal Area to concentrations detected in blanks and background samples reveals PCBs (aroclors 1242, 1254, and 1260) (0.29 mg/kg), cadmium (3.82 mg/kg), lead (56 mg/kg), Pb-210, Ra-226, Ra-228, U-234, U-235, and U-238 as chemicals of potential concern at the source. Ranges of concentrations are contained in Table B-4 of Appendix B.

Metals, including radionuclides, detected at concentrations above background levels in both the Inactive Fly Ash Disposal area and perched groundwater underneath it were cadmium, U-234, and U-238. U-234 and U-238 concentrations ranged from 3.7 ± 0.6 pCi/ℓ to 7.4 pCi/ℓ and from 2.1 ± 0.4 pCi/ℓ to 3.6 ± 0.7 pCi/ℓ, respectively. U-234 and U-238 were detected in Well 1047, located north of the Inactive Fly Ash Disposal Area. Cadmium was detected at a concentration of 0.009 mg/ℓ in Well 1047.

1.2.5 Southfield

The Southfield is a large, heterogeneous site that overlaps the boundaries of the Inactive Fly Ash Disposal Area. The Southfield was reportedly used as a burial site for construction rubble and soils that may have contained low levels of radioactivity; this includes debris from the razing of the old administration building. Chemicals and radionuclides detected in the Southfield at concentrations exceeding available background levels were PCBs (aroclors 1242, 1254, and 1260) (1100 µg/kg), acetone (280 µg/kg), chloroform (10 µg/kg), methylene chloride (280 µg/kg), toluene (26 µg/kg), cadmium (5 µg/kg), cobalt (27.7 µg/kg), lead (34 µg/kg), nickel (48 µg/kg), mercury (1.2 µg/kg), Pb-210, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-234, U-235, and U-238. Acetone and methylene chloride are common lab contaminants. Ranges of concentrations are contained in Table B-5 of Appendix B.

Radionuclides detected in concentrations above-background levels in both the Southfield and the perched groundwater beneath it were Th-228, Th-230, U-234, and U-238. Th-228 and Th-230 were detected in Well 1046 at concentrations of 1.1 ± 0.5 pCi/ℓ and 1.0 ± 0.5 pCi/ℓ, respectively. Well 1046 is located at the northern boundary of the Southfield. U-234 and U-238 detected in the perched groundwater beneath the Southfield ranged from 2.0 ± 0.5 pCi/ℓ to 2.8 ± 0.5 pCi/ℓ and from 1.9 ± 0.4 pCi/ℓ to 2.3 ± 0.5 pCi/ℓ, respectively.

Organics detected in the Southfield were not detected in the perched groundwater beneath the Southfield. This suggests that these organics have been contained within the Southfield or are bound in the surrounding glacial overburden.

1.2.6 Remedial Action Objectives

Remedial action objectives (RAOs) are medium-specific cleanup goals for protecting human health and the environment. They address the contaminants of concern as well as exposure routes and receptors identified in the baseline risk assessment. The primary purpose of RAOs is to ensure site-wide compliance with:

- Chemical-specific ARARs and to be considered (TBC) guidelines
- EPA guidance for risk to public health from hazardous chemicals
- Regulatory standards for control of radiation and radioactivity in the environment.

The remediation objectives for Operable Unit 2 must cover all constituents (radiological and chemical) that contribute to a reasonable maximum exposure (RME) scenario. Alternatives for remediation must meet airborne RAOs (at a point immediately adjacent to the waste units or at a location determined by an RME scenario to be of greatest risk to human and environmental receptors) as well as drinking water RAOs (in the aquifer that might be encountered directly below Operable Unit 2).

RAOs were developed based on chemical-specific and radionuclide-specific ARARs. The media for which RAOs were developed include: wastes, air, soils, sediments, surface water, and groundwater. RAOs are presented in Figure 1-2.

1.2.7 EPA Guidance

The EPA's "Guide for Conducting Treatability Studies Under CERCLA" outlines a three-tiered approach to conducting treatability studies for a Superfund site. The original interpretation of the approach can be seen in Figure 1-3.

MEDIA		REMEDIAL ACTION OBJECTIVE
1. WASTES		For Human Health:
	1-1	Prevent inhalation of/ingestion of/direct contact with OU2 wastes which would result in doses of non-carcinogens greater than the RfDs or in doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	1-2	Prevent migration of contaminants which would result in groundwater concentrations greater than the MCLs or that would result in doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06 or in doses of non-carcinogens greater than the RfDs.
	1-3	Prevent current and future direct radiation doses from exceeding 100 mrem/yr.
		For Environmental Protection:
	1-4	Prevent migration of contaminants that would result in surface water levels greater than ambient water quality criteria.
	1-5	Prevent current and future direct radiation doses from causing detectable chronic effects.
2. AIR		For Human Health:
	2-1	Prevent inhalation of contaminants which would result in doses greater than the RfD or doses which pose cancer risk levels greater than 1.0E-04 to 1.0E-06.
	2-2	Prevent inhalation of airborne radiation from exceeding a 10 mrem/yr dose, and radon flux from exceeding 20pCi/square meter/second.
		For Environmental Protection:
	2-3	Prevent current and future radiation emissions from causing detectable chronic effects.

FIGURE 1-2. REMEDIAL ACTION OBJECTIVES

MEDIA		REMEDIAL ACTION OBJECTIVE
3. SOILS		For Human Health:
	3-1	Prevent inhalation of/ingestion of/direct contact with soils surrounding the OU2 wastes which result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	3-2	Prevent migration of contaminants which would result in groundwater concentrations greater than the MCLs or that would result in doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06 or doses of non-carcinogens greater than the RfDs.
	3-3	Prevent contact with radium and thorium above 5 pCi/g in the first 15 cm of soil, and 15 pCi/g at lower depths. Prevent contact with other nuclides at concentrations resulting in doses greater than 100 mrem/yr.
		For Environmental Protection:
	3-4	Prevent migration of contaminants that would result in surface water contamination levels greater than ambient water quality criteria.
4. SEDIMENTS		For Human Health:
	4-1	Prevent ingestion of/direct contact with sediment contaminants which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
		For Environmental Protection:
	4-2	Prevent releases of contaminants from sediments that would result in surface water contamination levels greater than ambient water quality criteria.

FIGURE 1-2. REMEDIAL ACTION OBJECTIVES (continued)

MEDIA		REMEDIAL ACTION OBJECTIVE
5. SURFACE WATER	5-1	For Human Health: Prevent ingestion of water having contaminants greater than the MCLs or which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	5-2	For Environmental Protection: Restore surface water to below ambient water quality criteria.
6. GROUNDWATER	6-1	For Human Health: Prevent ingestion of water having contaminant levels greater than the MCLs or TBCs, or which would result in doses of non-carcinogens greater than the RfDs or doses of carcinogens posing cancer risk levels greater than 1.0E-04 to 1.0E-06.
	6-2	For Environmental Protection: Restore groundwater aquifer to contaminant concentrations below the MCLs.

FIGURE 1-2. REMEDIAL ACTION OBJECTIVES (continued)

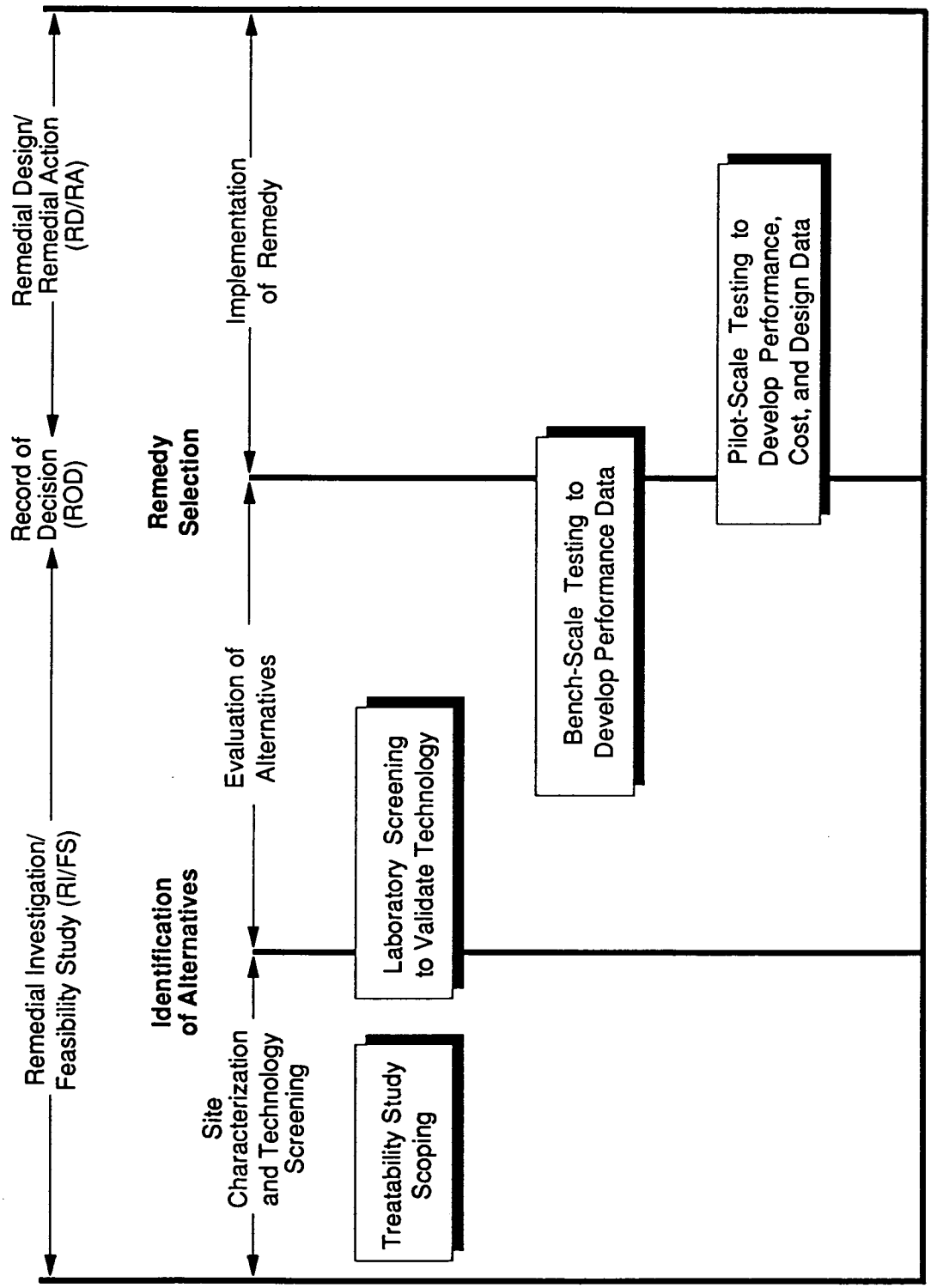

Figure 1-3. The Role of Treatability Studies in the RI/FS and RD/RA Process.

Source: Guide for Conducting Treatability Studies under CERCLA. Interim Final 12/89.

Since publication, the terminology of this approach has been revised as follows:

- Remedy screening
- Remedy selection
- Remedy design

The three levels of treatability testing are divided into pre-record of decision (ROD) and post-ROD studies. The remedy screening and remedy selection testing are pre-ROD studies, and the remedy design studies are post-ROD. Figure 1-4 illustrates these three levels of treatability testing and how this treatability study work plan compares with these requirements.

Pre-ROD treatability studies provide the critical performance and cost data needed to (1) evaluate all potentially applicable treatment alternatives and (2) select an alternative for remedial action based on the nine RI/FS evaluation criteria. The detailed analysis of alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD. During the detailed analysis, all remedial alternatives are evaluated based on nine RI/FS evaluation criteria. These criteria are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

These criteria are described in detail in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988).

Remedy screening is the first step in the tiered approach. Its purpose is to determine the feasibility of a treatment alternative for the contaminants/matrix of interest. These tests are typically conducted under conditions that are favorable to the technology. These small-scale studies are designed to provide a qualitative evaluation of the technology and are conducted with minimal levels of quality assurance/quality control (QA/QC). Tests conducted under this tier are generic in nature (not vendor specific). If the feasibility of the treatment cannot be demonstrated, the alternative generally should be screened out at this time.

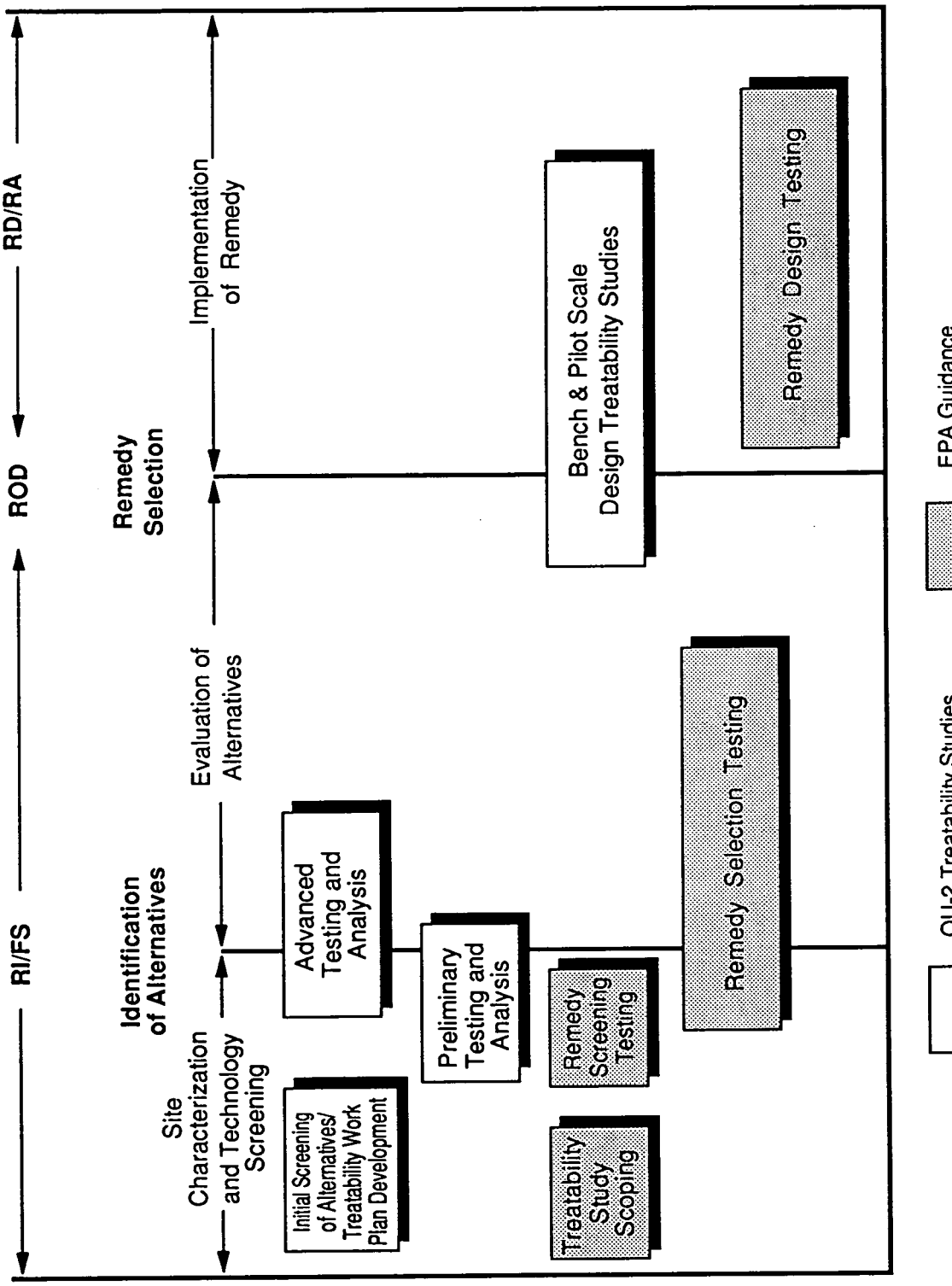

Figure 1-4. Relationship of the Operable Unit 2 Treatability Studies to the RI/FS Process

The remedy selection tier of the treatability study program is designed to determine whether a treatment alternative can meet the operable unit's cleanup criteria and at what cost. The purpose of this tier is to generate the performance and cost data necessary for remedy evaluation in the detailed analysis of alternatives phases of the FS. The cost data developed in this tier should support costs estimates of +50 percent to -30 percent accuracy. The performance data will be used to determine whether this technology will meet ARARs or cleanup goals. Remedy selection studies are typically small scale, incorporating generic tests using bench- or pilot-scale equipment in either the laboratory or the field. The study costs are higher than those encountered in the remedy screening tier and require longer durations to complete. The levels of QA/QC are moderate to high, because the data from these studies will be used to support the ROD.

In the post-ROD remedy design tier treatability study, detailed scale-up design, performance, and cost data are generated to implement and optimize the selected remedy. Remedy design studies are performed after the ROD, usually as part of the remedy implementation. These studies are performed on full-scale or near full-scale equipment, for the purpose of generating detailed, scale-up design and cost data. These studies should focus on optimizing process parameters, which is not a part of this treatability study. Remedy design studies require moderate to high QA/QC and are typically vendor specific.

This work plan covers the remedy screening and remedy selection tiers of the treatability studies. The remedy screening is performed in the preliminary screening study, and the remedy selection is performed in the advanced treatability study.

1.3 TREATABILITY STUDY DESCRIPTION

1.3.1 General

As discussed in Section 1.1, this treatability study consists of preliminary and advanced stages. Preliminary Stage I testing will consist of evaluating various mixtures of reagents and waste to determine those mixtures which demonstrate favorable compressive strength properties. If a minimum of six samples do not achieve adequate compressive strength (approximately 500 pounds per square inch [psi] measured by unconfined compressive strength [UCS] testing), then Preliminary Stage II testing will begin. Stage II will consist of one to ten additional formulations which will be determined based in part on the results of Stage I. UCS testing will be performed on all Stage II samples. The advanced testing will consist of TCLP and permeability tests performed on those samples which have compressive strength of approximately 500 psi. The estimated number of experiments are shown in Table 1-2. The concentrations contained in the TCLP extract analyzed for chemicals of concern will be considered representative of concentrations of leachate generated from treated waste for purposes of alternative comparison in the FS. Leachate concentrations from the TCLP tests will be used as input for groundwater fate and transport modeling.

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TABLE 1-2
ESTIMATED NUMBER OF EXPERIMENTS FOR CEMENT STABILIZATION

	Remedy Screening (Preliminary)		Remedy Selection (Advanced)	
	Stage I	Stage II		
Waste Type	UCS (28-day cured sample)	UCS (28-day cured sample)	TCLP	Permeability
Sanitary Landfill	12	0-10	6 minimum	6 minimum
Lime Sludge Pond	16	0-10	6 minimum	6 minimum
Southfield	12	0-10	6 minimum	6 minimum
Subtotal	40	0-30	18 minimum	18 minimum
Duplicate (20%)	8	0-6	4 minimum	4 minimum
Total	48	0-36	22 minimum	22 minimum

1.3.2 Specific Treatability for Individual Waste Units Within Operable Unit 2

1.3.2.1 Sanitary Landfill

Samples of landfill waste will be burned in a lab furnace in order to generate ash samples for solidification studies. The waste samples will be weighed when they are received. Certain types of material may require segregation prior to burning in the laboratory furnace, such as rubber or metallic fragments. These samples will be weighed both before burning and after burning is completed so that percent reduction can be estimated. The ash will be mixed with other reagents (as discussed in Section 4.0) and analyses performed as discussed in Section 1.3.1.

1.3.2.2 Lime Sludge Ponds

Lime sludge waste will be mixed with other reagents (as discussed in Section 4.0) and analyses performed as discussed in Section 1.3.1.

1.3.2.3 Southfield

Southfield waste will be mixed with other reagents (as discussed in Section 4.0) and analyses performed as discussed in Section 1.3.1.

1.3.2.4 Inactive and Active Fly Ash Disposal Areas

Specific tests involving solidification of FMPC fly ash alone are not being conducted as part of this study, since FMPC fly ash (from the Active Fly Ash Disposal Pile) is being used as one of the reagents. Should the reagent mixture prove effective for Operable Unit 2 (and/or other operable units), it is likely that a substantial quantity of FMPC fly ash will be utilized in the solidification of Operable Unit 2 and/or other operable unit wastes. Waste from the Inactive Fly Ash Disposal Area also is being considered for the study (on a more limited scale) and is a potential source should the Active Fly Ash Pile be depleted. It is noteworthy that ash from both the Active and Inactive Fly Ash Disposal Areas is being examined for potential use as an additive for treatment of Operable Units 1 and 4 wastes, for both cement solidification and vitrification technologies. Should either of these technologies prove viable, the need for solidification of FMPC fly ash may become nonexistent. Should residual amounts of fly ash remain after treatment of other wastes, comparison studies (treatment versus nontreatment) made for the other Operable Unit 2 wastes should be valid for fly ash as well.

1.3.3 General Selection Criteria

For cement stabilization, the most promising formulations will have UCS, after a 28-day curing period, of approximately 500 psi; will pass all of the TCLP leaching requirements; will have relatively low permeability; and will have minimal volume increase after treatment. Appendix A contains a more detailed discussion of the justification for using a compressive strength of approximately 500 psi.

The best technology will be determined by comparison of multiple criteria during the detailed analysis. The detailed analysis of alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD. During the detailed analysis, all remedial alternatives are evaluated based on nine RI/FS evaluation criteria (see Section 1.2.7).

The relationship between the evaluation criteria and the data that will be generated during treatability studies is shown in Table 1-3.

Compliance with ARARs would be determined by whether the treated material meets compressive strength requirements for disposal, whether the leachate exceeds established discharge standards, and on factors relating to waste form. A full evaluation of the technology for compliance with ARARs will be performed in the FS.

Treatability testing that relates to a technology's long-term effectiveness and permanence include its shear strength and durability for handling and disposal purposes, its solubility as measured by leachability, and the extent to which it transmits water based on permeability. The waste form itself also influences long-term stability.

The ability of a technology or formulation to reduce the toxicity, mobility, or volume will be measured by indicators such as: bulking factor for volume determination; leachate analysis for toxicity determinations; and permeability for mobility reduction.

Short-term effectiveness is impacted primarily by bulking factor, which is an indicator of the volume of treated waste that must be handled and disposed of and by the specific technology chosen.

The implementability of a particular technology is influenced by the volume of waste to be handled as measured by bulking factor and by the waste form itself. As with implementability, cost is impacted by the technology selected and the volume of waste to be treated.

The final two evaluation criteria, state and community acceptance, are influenced by the results of all the data and by the other seven criteria.

Additional information on use of the evaluation criteria and treatability data in the feasibility study process can be found in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988).

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TABLE 1-3

RELATIONSHIP OF TREATABILITY DATA TO FS EVALUATION CRITERIA

	Treatability Data			
FS Evaluation Criteria	Compressive Strength (UCS)	Leachate Analysis (TCLP)	Bulking Factor (% volume change)	Permeability
Overall protection of human health and the environment	X	X		X
Compliance with ARARs	X	X		
Long-term effectiveness and permanence	X	X		X
Reduction of toxicity, mobility, or volume through treatment		X	X	X
Short-term effectiveness			X	
Implementability			X	
Cost			X	
State acceptance	X	X	X	X
Community acceptance	X	X	X	X

1.4 APPENDICES

This work plan contains four appendices that provide additional information supporting the treatability study. Appendix A provides additional justification for (1) using the portland cement/fly ash process to solidify waste, and (2) using the UCS of approximately 500 psi. Appendix B is a description of Operable Unit 2 waste characteristics. Appendix C is the health and safety plan for the treatability program for Operable Unit 2. Appendix D contains standard operating procedures for determining bulking factor measurement, for determining UCS, and for entering data into laboratory notebooks.

2.0 REMEDIAL TECHNOLOGY DESCRIPTION

2.1 SUMMARY OF ALTERNATIVES

The following sections discuss alternatives for each of the Operable Unit 2 waste areas. A comprehensive description of these alternatives is contained in the final ISA Report For Operable Unit 2 (DOE 1991). The alternatives listed represent those which survived the initial screening phase and are proposed for further analysis as part of the FS. The no-action alternative that is proposed in the ISA for each of the waste areas would involve no implementation of corrective action; but under this alternative, ongoing water quality monitoring would continue.

As stated in Section 1.3.1, results obtained from the treatability study will be considered representative of leachate concentrations of treated waste for use in groundwater fate and transport modeling of removal and treatment alternatives. In order to provide comparative data for nonremoval and nontreatment alternatives, leaching experiments using the TCLP will be performed on untreated waste (conducted under a separate program) to support groundwater fate and transport analysis. It is noteworthy that the Lime Sludge Ponds are candidates for in situ solidification/stabilization, and therefore will not be a part of this treatability study.

2.1.1 Sanitary Landfill

Alternative 1: Containment

Under this alternative, the waste would remain in place. Access restrictions, monitoring activities, capping, and runoff control would be implemented.

Alternative 2: Containment with Perched Groundwater Treatment

This alternative is identical to Alternative 1, except that the perched groundwater underlying the waste areas would be removed and treated. Pumping wells would be utilized to remove groundwater contained within these saturated sand lenses present in the glacial overburden.

Alternative 5: Removal and Treatment of Waste, Perched Groundwater Treatment, and On-Property Disposal

This alternative combines access restrictions, monitoring, and runoff control with mechanical removal; treatment and on-property disposal of waste materials; and removal and treatment of perched groundwater. The technologies that would be utilized for waste treatment are rotary kiln incineration and cement-based stabilization of treatment residuals.

Alternative 6: Removal and Treatment of Waste, Perched Groundwater Treatment, and Off-Site Disposal

This alternative is identical to Alternative 5, except that the waste would be disposed of at an off-site location after its removal and treatment.

2.1.2 Lime Sludge Ponds

Alternative 1: Containment with In Situ Stabilization

Under this alternative the waste would remain and be stabilized in place, using shallow-soil-mixing (SSM) technology. This involves the use of a device suspended from a crane to inject and mix the lime sludges with a mixture of cement and fly ash to produce a stabilized end product that could support the weight of a cap. Access restrictions, monitoring activities, capping, and runoff control also would be implemented.

Alternative 2: Containment with In Situ Stabilization and Perched Groundwater Treatment

This alternative is identical to Alternative 1 except that perched groundwater underlying waste areas would be removed and treated. Pumping wells would be utilized to remove groundwater contained within these saturated sand lenses present in the glacial overburden.

Alternative 3: Removal and Treatment of Waste, Perched Groundwater Treatment, and On-Property Disposal

This alternative combines access restrictions, monitoring, and runoff control with mechanical removal, treatment, and on-property disposal of waste materials, and removal and treatment of perched groundwater. The technology that would be utilized for waste treatment is solidification using a cement/fly ash mixture and applying a process similar to that used in producing concrete in a batch plant.

Alternative 4: Removal and Treatment of Waste, Perched Groundwater Treatment, and Off-Site Disposal

This alternative is identical to Alternative 3, except that the waste would be disposed of at an off-site location after removal and treatment.

2.1.3 Fly Ash/Southfield Area

The Fly Ash/Southfield area comprises three distinct areas: the Active Fly Ash Pile, the Inactive Fly Ash Disposal Area, and the Southfield. The Inactive Fly Ash Disposal Area is adjacent to the Southfield. The Active Fly Ash Pile is separated from the Southfield by an unpaved road.

Alternative 1: Containment

Under this alternative the waste would remain in place. Access restrictions, monitoring activities, capping, and runoff control would be implemented.

Alternative 2: Containment with Perched Groundwater Treatment

This alternative is identical to Alternative 1, except that the perched groundwater underlying the waste areas would be removed and treated. Pumping wells would be utilized to remove groundwater contained within these saturated sand lenses present in the glacial overburden.

Alternative 5: Removal and Treatment of Waste, Perched Groundwater Treatment, and On-Property Disposal

This alternative combines access restrictions, monitoring, and runoff control with mechanical removal, treatment, and on-property disposal of waste materials, and removal/treatment of perched groundwater. The technology that would be utilized for waste treatment is solidification, using a mixture of cement and fly ash and applying a process similar to that used for production of concrete in a batch plant.

Alternative 6: Removal and Treatment of Waste, Perched Groundwater Treatment, and Off-Site Disposal.

This alternative is identical to Alternative 5, except that the waste would be disposed of at an off-site location after removal and treatment.

2.2 SOLIDIFICATION OF WASTE MATERIAL

Solidification/stabilization immobilizes contaminants in soils and sludges by binding them in a concrete-like, leach-resistant matrix. Contaminated waste materials are collected, screened to remove oversized material, and introduced to a batch mixer. The waste material is then mixed with water, fly ash, portland cement, and possibly other reagents. The quantity of water added depends upon the existing moisture content of the waste and the total moisture content required to provide proper solidification. The treated waste will form a solid mass with significant UCS, high stability, and a rigid texture similar to that of concrete.

2.2.1 Cement Stabilization for Operable Unit 2 Treatability Study

The waste samples will be treated with varying combinations of cement, sodium silicate, clay, zeolite, and fly ash from the Active Fly Ash Pile to determine the viability of the cement stabilization option. Portland Type I or II cements, PQ Corporation Type N sodium silicates, Operable Unit 2 fly ash, attapulgite, clinoptilolite, and water will be used in various combinations to determine the optimum overall mix. Site fly ash will be used as a pozzolanic agent in the screening in an effort to determine its effectiveness in achieving an adequate stabilized waste form.

A limited number of test runs will be made using samples obtained from the Inactive Fly Ash Disposal Area, for comparison with results obtained from the Active Fly Ash Pile. Section 4.0 contains more details on the experimental design.

3.0 TEST AND DATA QUALITY OBJECTIVES

The purpose of this preliminary screening is to assess the performance of various stabilization technologies on the Operable Unit 2 wastes in support of the RI/FS. To select a preferred alternative for the Operable Unit 2 RI/FS, a waste treatment technology must be screened to support evaluations of the alternative during the detailed analysis of alternatives. In addition, the level of QA/QC applied during experimentation and analysis must be established.

This section will establish the performance objectives for the treatment technologies, the additional data desired for use in subsequent stages of the RI/FS, and the data quality objectives (DQOs).

3.1 PERFORMANCE OBJECTIVES AND DESIRED DATA

Specific test objectives have been established so that the performance of the various stabilization mixtures can be evaluated in the areas of leachability, UCS, and final waste form volume. These performance objectives will be used to determine whether a particular reagent mixture produces an acceptable waste form. The specific objectives of the preliminary and advanced stages are as follows:

- To determine the cement stabilization reagents and relative quantities required, so that the final waste form meets TCLP criteria
- To determine the cement stabilization reagents and relative quantities required, so that the final waste form achieves a UCS (American Society of Testing and Materials [ASTM] D2166) of approximately 500 psi
- To estimate the volumes of treated waste that will be generated by each process
- To provide preliminary cost and design data for the FS
- To provide leaching characteristics of solidified waste for use in fate and transport modeling, using results obtained from the TCLP.
- To develop preliminary reagent mixtures
- To develop preliminary process parameter data for use in the advanced phase studies for cement solidification, i.e., shear strength, waste form temperature rise with reagent addition, general description of waste before and after reagent addition, and permeability (EPA Method 9100, EPA 1986)
- To obtain the chemical and radiological data as shown in Table 3-1.

The chemicals and radionuclides listed in Table 3-1 represent a general list for the FMPC. The contaminants of concern listed in Table 1-1 were determined based on limited characterization data obtained prior to the current field characterization program being conducted for Operable Unit 2. Before analyzing for

TABLE 3-1
CHEMICAL AND RADIOLOGICAL INFORMATION TO BE ACQUIRED IN ADVANCED STUDY

TCLP Analysis List[a]

Organics[b]	Inorganic Chemicals[c]	Radionuclides[d]
TCL volatiles	Aluminum (Al)	Radium-226
TCL semivolatiles	Antimony (Sb)	Radium-228
TCL pesticides/PCBs	Arsenic (As)	Total thorium
	Barium (Ba)	Total uranium
	Boron (B)	
	Calcium (Ca)	
	Chromium (Cr)	
	Cobalt (Co)	
	Copper (Cu)	
	Cyanide (CN)	
	Iron (Fe)	
	Lead (Pb)	
	Magnesium (Mg)	
	Manganese (Mn)	
	Mercury (Hg)	
	Molybdenum (Mo)	
	Potassium (K)	
	Nickel (Ni)	
	Selenium (Se)	
	Silver (Ag)	
	Sodium (Na)	
	Thallium (Tl)	
	Vanadium (V)	
	Zinc (Zn)	

[a] Analysis by Contract Laboratory Protocol (CLP).

[b] Organics will be performed only if found in the characterization study.

[c] Inorganic chemicals will only be analyzed for if determined to be of concern from additional data being collected as part of the RI/FS for Operable Unit 2. In addition, inorganic chemicals listed in Table 1 of 40CFR261.24 will be analyzed to determine if the waste exhibits the RCRA characteristic of toxicity.

[d] If additional radionuclides are determined to be concern of Operable Unit 2, they will be analyzed for; isotopic distributions will be obtained from site characterization.

the inorganic chemicals listed in Table 3-1, a determination will be made based on the existing data plus the new data as to which inorganic chemicals are of concern. Analysis for the revised list of chemicals of concern will then be done.

3.2 DATA QUALITY OBJECTIVES

DQO analytical levels are defined in EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1989). This guide states that the requisite analytical levels are dictated by the types and magnitudes of decisions to be made, based on the data and the objective of the screening. A description of the analytical levels is presented in Table 3-2, an excerpt from EPA's guide. A discussion of the DQOs for each stage of laboratory screening for cement stabilization follows.

The establishment of DQOs is the part of the process that defines the data quality needs of the project. The implementation of an appropriate QA/QC program is required to ensure that data of known and documented quality are generated. The DQOs will define the level of QA/QC for the treatability testing and analysis. The DQOs for this laboratory screening are quantitative in nature because the stabilized waste must meet specific performance criteria, namely UCS of approximately 500 psi (see Appendix A) and TCLP. A list of tests and associated DQOs for cement stabilization are in Tables 3-3 and 3-4.

3.2.1 Preliminary Screening - Stage I

The preliminary screening will be an initial run of a minimum of 12 formulations for each of the three waste types (Sanitary Landfill, Lime Sludge Ponds, and the Southfield). All stabilized waste samples will be tested for shear strength and temperature rise after mixing waste and reagents. UCS tests will be performed on samples at 28 days. The 28-day samples will be tested for bulking factor, and those that meet UCS criteria will also be tested for TCLP (Table 3-1) under the advanced study. The TCLP samples will not be analyzed for organics unless organics are present in the waste.

The bulk density of the treated waste will be calculated by dividing the weight of the UCS solid cylinder (2 inches x 4 inches) by its volume. (See EPA 1989, EPA/625/6-89/022, Section 4.2.4, for a description of bulk density measurement of stabilized waste.)

TABLE 3-2
SUMMARY OF ANALYTICAL LEVELS

Level I	
Type of analysis	Field screening or analysis with portable instruments.
Limitations	Usually not compound-specific, but results are available in real time. Not quantifiable.
Data quality	Can provide an indication of contamination presence. Few QA/QC requirements.
Level II	
Type of analysis	Field analyses with more sophisticated portable instruments or mobile laboratory. Organics by GC; inorganics by AA, ICP, or XRF.
Limitations	Detection limits vary from low parts per million to low parts per billion. Tentative identification of compounds. Techniques/instruments limited mostly to volatile organics and metals.
Data quality	Depends on QA/QC steps employed. Data typically reported in concentration ranges.
Level III	
Type of analysis	Organics/inorganics performed in an off-site analytical laboratory. May or may not use CLP procedures. Laboratory may or may not be a CLP laboratory.
Limitations	Tentative identification of compounds in some cases.
Data quality	Detection limits similar to CLP. Rigorous QA/QC.
Level IV	
Type of analysis	Hazardous Substances List (HSL) organics/inorganics by GC/MS, AA, ICP. Low parts-per-billion detection limits.
Limitations	Tentative identification of non-HSL parameters. Validation of laboratory results may take several weeks.
Data quality	Goal is data of known quality. Rigorous QA/QC.
Level V	
Type of analysis	Analysis by nonstandard methods.
Limitations	May require method development or modification. Method-specific detection limits. Will probably require special lead time.
Data quality	Method-specific.

SOURCE: EPA, "Guide for Conducting Treatability Studies under CERCLA," December 1989.

TABLE 3-3

CEMENT STABILIZATION TEST DATA QUALITY OBJECTIVES
PRELIMINARY (REMEDY SCREENING)

Test	Comment	Data Quality Objective Level
Bulking factor by density calculation	Minimize waste volume increase. To estimate the volume of waste that will be generated.	I
Unconfined Compressive Strength (UCS) (ASTM D2166)	To determine the stabilization reagent formulation so that the final waste form achieves UCS of approximately 500 psi. Also to provide preliminary cost and design data for the RI/FS.	III
Waste form temperature rise	To provide preliminary process parameters	I
Shear strength	To provide preliminary process parameters	I

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TABLE 3-4

CEMENT STABILIZATION TEST DATA QUALITY OBJECTIVES
ADVANCED (REMEDY SELECTION)

Test	Comment	Date Quality Objective Level
TCLP	To determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. To provide data for the FS risk assessment calculations.	III
Permeability	To provide data for the FS risk assessment calculations.	III

The bulking factor is calculated as shown:

$$BF = \frac{100*(100+A)/P_t - 100/P_r}{100/P_r}$$

where

BF = percent bulking factor
A = percent additives added
P_t = density of treated waste
P_r = density of raw waste

The temperature, shear strength and bulking factor are DQO analytical Level I. The UCS and TCLP are DQO analytical Level III.

3.2.1.1 Compositing of Waste Samples for Preliminary Stage Testing

Discrete archived samples of waste from the Sanitary Landfill, the Lime Sludge Ponds, and the Southfield will be composited at the FMPC before shipment to the lab. Discrete samples will be taken at random depths from a particular borehole and composited with discrete samples from other boreholes, resulting in a fairly uniform waste mixture. Landfill samples will be composited prior to burning.

Active fly ash (used as a reagent) will be composited in the same manner as the waste (to be solidified) and will not be mixed with inactive fly ash. Inactive fly ash (used as a reagent) will also be composited in the same manner as the waste (to be solidified).

3.2.2 Preliminary Screening - Stage II

The Stage II experiments may consist of one to 10 new formulations if results of Stage I testing identify this to be necessary. The samples will be tested for shear strength and temperature rise after mixing waste and reagents. The bulking factor and UCS will be run after 28 days of curing.

3.2.3 Advanced Stage Experiments

TCLP leach tests and permeability tests will be performed on a minimum of six samples achieving a minimum compressive strength of approximately 500 psi. The results of the leach tests will be evaluated and used in determining representative leachate concentration for groundwater fate and transport modeling. EPA method 9100 (EPA 1986) will be used as a guide for permeability testing of solidified waste samples.

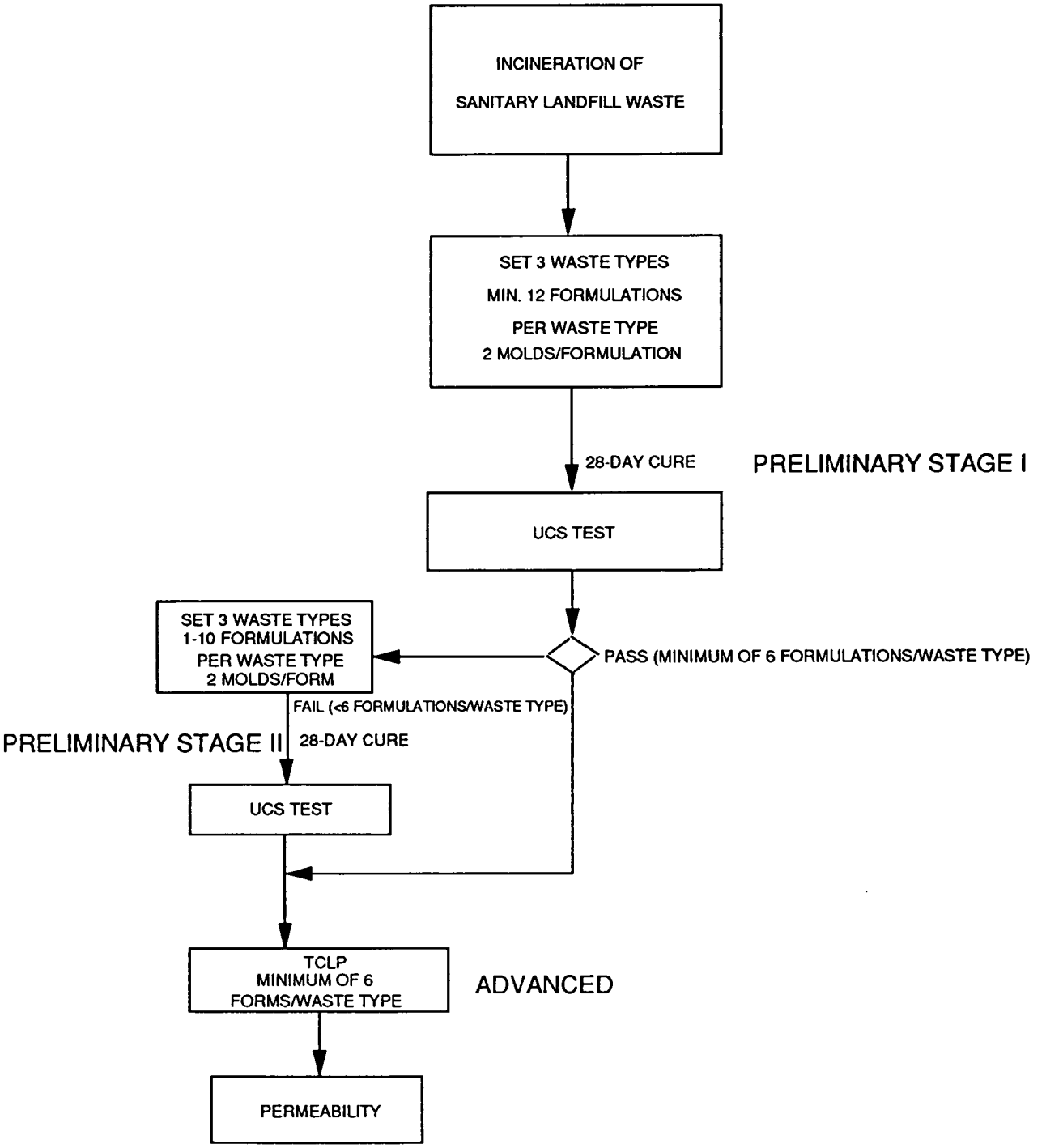
4.0 EXPERIMENTAL DESIGN AND PROCEDURES

4.1 PRELIMINARY (STAGE I) SCREENING

There are many unknown variables involved in the behavior and activity of the waste and the performance of the proposed reagents with the waste. Since there is no way of knowing in advance which reagent combination will provide optimal performance, a matrix of experimental tests has been created for the Operable Unit 2 wastes. If the results of the tests indicate that a particular reagent combination(s) will not produce the desired results, then that combination(s) will be eliminated from consideration. As discussed in Section 4.1.4, additional testing may be required if more data are needed to evaluate the performance of various reagent combinations. A flow chart of the overall testing process is shown in Figure 4-1.

The rationale used for the reagent combinations shown in Tables 4-1 through 4-3 is contained in Appendix A. FMPC fly ash samples from the Active Fly Ash Pile are being utilized in this study because of its value to resource recovery. The overall volume increase for Operable Unit 2 can be minimized by utilizing this source of material for solidification/stabilization, provided the FMPC fly ash proves effective in this type of use. On a limited basis, some comparative samples of Inactive Fly Ash will be substituted for Active Fly Ash so that comparisons can be made. Conner (1990) also discusses different types of materials and processes used in stabilization/solidification. Generally, water/cement ratios are approximately 0.3 and fly ash/cement ratios range from 2 to 4. Due to the existence of moisture in Operable Unit 2 wastes, the water (to be added) is shown as a range because of the likelihood of differing moisture contents in the waste and fly ash.

The procedure to be followed will involve the following steps. Fly ash (used as a mixture) will be ground to pass through a 3/8-inch mesh screen before mixing testing since the fly and bottom ash have historically been codisposed of at the FMPC. Obvious debris, noncoal ash, or other foreign substances will be removed. Waste material from the landfill, sludge ponds, and Southfield will also be ground to pass a 3/8 inch mesh screen. The percent of volume removed weight and visual observation will be noted. In the preliminary phase, waste and correct amounts of reagents (Tables 4-1 through 4-3) will be mixed in a plastic container, slightly compacted by tapping with a bolt, and sealed within the container with a lid. Enough mixture to make two cylinders for UCS testing will be produced for each formulation for each waste stream. The amount of water added will be determined empirically; enough water will be added to make the mixture into a paste. If too much bottom ash is present in the fly ash, a commercial fly ash may be substituted. Mixing will be done by hand with a spatula until the mixture has an even consistency without any lumps.



NOTE:

BULKING FACTOR ANALYSES WILL BE DONE PRIOR TO USC TESTS.
SHEAR STRENGTH AND TEMPERATURE RISE ANALYSIS WILL BE PERFORMED WHEN SAMPLES ARE MIXED.

FIGURE 4-1. FLOW CHART OF TREATABILITY TESTING FOR OPERABLE UNIT 2

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TABLE 4-1
SANITARY LANDFILL ASH

CONSTITUENTS FOR STABILIZATION PER SAMPLE IN GRAMS						
Run No.	Waste[a] (Ash)	Type I Portland Cement	FMPC Fly Ash	Sodium Silicate	Attapulgite & Clinoptilolite Each	Potential Range of Water Required
1	300	75	150	0.00	15	15-60
2	300	75	150	0.15	0.00	15-60
3	300	75	150	0.15	15	15-60
4	300	75	75	0.00	15	15-60
5	300	75	75	0.15	0.00	15-60
6	300	150	150	0.00	5	30-60
7	300	150	150	0.15	0.00	30-60
8	300	150	75	0.00	5	30-60
9	300	150	75	0.15	0.00	10-20
10	300	45	90	0.00	3	12-18
11	300	45	90	0.09	0.00	12-18
12	300	45	90	0.09	3	12-18

TABLE 4-2
LIME SLUDGE POND WASTE

CONSTITUENTS FOR STABILIZATION PER SAMPLE IN GRAMS						
Run No.	Waste[a]	Type II Portland Cement	FMPC Fly Ash	Sodium Silicate	Attapulgite & Clinoptilolite Each	Potential Range of Water Required
1	300	75	150	0.00	15	0-60
2	300	75	150	0.15	0.00	0-60
3	300	75	150	0.15	15	0-60
4	300	75	75	0.00	15	0-60
5	300	75	75	0.15	0.00	0-60
6	300	150	150	0.00	15	0-120
7	300	150	150	0.15	0.00	0-120
8	300	150	75	0.00	15	0-120
9	300	150	75	0.15	0.00	0-120
10	300	45	90	0.00	9	0-36
11	300	45	90	0.09	0.00	0-36
12	300	45	90	0.09	9	0-36
13	300	150	150	0.00	15	0-180
14	300	150	150	0.15	0.00	0-180
15	300	150	150	0.00	15	0-180
16	300	150	150	0.15	0.00	0-180

[a] Wet weight of waste

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TABLE 4-3
SOUTHFIELD WASTE

CONSTITUENTS FOR STABILIZATION PER SAMPLE IN GRAMS						
Run No.	Waste[a]	Type I Portland Cement	FMPC Fly Ash	Sodium Silicate	Attapulgite & Clinoptilolite Each	Potential Range of Water Required
1	300	75	150	0.00	15	0-75
2	300	75	150	0.15	0.00	0-75
3	300	75	150	0.15	15	0-75
4	300	75	75	0.00	15	0-75
5	300	75	75	0.15	0.00	0-75
6	300	150	150	0.00	15	0-150
7	300	150	150	0.15	0.00	0-150
8	300	150	75	0.00	15	0-150
9	300	150	75	0.15	0.00	0-150
10	300	75	150[b]	0.00	9	0-75
11	300	75	150[b]	0.09	0.00	0-75
12	300	75	150[b]	0.09	9	0-75

[a] Wet weight of waste
[b] Substitute Inactive Fly Ash for Active Fly Ash

After mixing, shear strength and temperature rise will be measured. The treated samples will be cured at room temperature in the sealed containers. After 28 days, one of each set of two test cylinders will be subjected to UCS tests. Those samples which are acceptable will then be subjected to TCLP testing under the advanced program. If less than six formulations for each waste stream are judged to be successful, Stage II (see 4.1.5) will be initiated with new formulations.

4.1.1 Sanitary Landfill Ash

Waste from the Sanitary Landfill will be placed in a lab furnace for two hours at approximately 200°C, then two more hours at approximately 550°C. The resulting ash will be used to conduct the treatability studies for solidification.

Stabilization reagents will be blended with landfill ash in a graduated plastic cup and mixed by hand, using a spatula, until they are homogeneous (more than two minutes). Each composite sample will be dosed with stabilization reagents according to the stabilization matrix (see Table 4-1). FMPC fly ash (from the Active Fly Ash Pile) is being used in these experiments. UCS measurements using method ASTM D2166 will be taken on day 28. Those judged to be acceptable will be subjected to TCLP tests (Table 3-1) under the advanced program.

4.1.2 Lime Sludge Ponds

Stabilization reagents will be blended with pond waste in a graduated plastic cup and mixed by hand, using a spatula, until they are homogeneous (more than two minutes). The cup is then covered with a tight-fitting lid. Each sample will be prepared according to the stabilization matrix (see Table 4-2). Type II portland cement is used instead of Type I due to possible sulfate reactions between the reagents and sludge wastes.

4.1.3 Southfield

Stabilization reagents will be blended with waste in a graduated plastic cup and mixed by hand, using a spatula, until they are homogeneous (more than two minutes). The cup is then covered with a tight-fitting lid. Each composite sample will be prepared according to the stabilization matrix (see Table 4-3).

4.1.4 Data Required

The following data will be recorded during cement stabilization preliminary screening:

- UCS (ASTM D2166)
- Bulking factor
- Waste form temperature rise, after waste and reagents are mixed
- General descriptions of the waste, before and after reagent addition
- Approximate shear strength, measured within 10 minutes after waste and reagents are mixed

- Physical characteristics—percent moisture and bulk density
- The amount of water added to each waste form.

4.1.5 Preliminary (Stage II) Screening

Results from the Stage I runs may not yield six successful mixtures. If this is the case, an additional experimental matrix will be designed to gather this data. This additional testing could consist of from one to 10 experiments. The test procedures and data requirements are the same as the Stage I screening. Two molds will be cast for each formulation, with one being used for the Stage II UCS test.

4.2 ADVANCED TESTING

Those formulations passing Stage I or Stage II 28-day UCS tests will be subjected to the advanced testing. This will involve a minimum of six formulations for each of the three types of waste. TCLP tests will be conducted utilizing the sample specimen used previously for preliminary Stage I or II testing. Permeability testing for the advanced testing will utilize the other mold.

4.2.1 Data Requirements for Advanced Testing

The following data will be recorded during advanced testing:

- Results of TCLP tests performed on solidified waste sample
- Permeability (EPA Method 9100)

5.0 EQUIPMENT AND MATERIALS

The equipment and materials needed for each test will be established and supplied by International Technology (IT) Corporation, the subcontractor performing the solidification experiments and analytical analysis. Table 5-1 lists the major equipment to be used for this treatability study.

TABLE 5-1
EQUIPMENT AND MATERIALS[a]

Number of Items	Description
Multiple	Plastic containers, 8 oz. and 5 oz.
Multiple	Spatulas
Multiple	Crucibles
1	HACH digital pH meter
1 or more	Laboratory furnace
1	Soiltest Laboratory vibrating shaker
1	Thermometer, calibrated and traceable
1	Scale, calibrated
1	Soiltest Torvane
Multiple	2 x 4 Jatco Co. plastic molds for UCS
1	Hobart ASTM Grade Planetary Mixer
1	Drying oven
Multiple	Crucible tongs

[a] Additional equipment used to perform analytical tests (e.g., GC/MS, etc.) are not listed. Additional equipment requirements are also listed in the standard operating procedures contained in Appendix D.

6.0 SAMPLING AND ANALYSIS

The samples collected for the purpose of these tests will be obtained from archived samples gathered under the Work Plan Addendum for Operable Unit 2, "Additional Sampling Activities for Operable Unit 2" (DCR41).

Upon completion of the treatability study, all wastes will be drummed and returned to the Fernald site (currently operated by Westinghouse Environmental Management Company of Ohio [WEMCO]). All Department of Transportation requirements must be met for transport of these wastes.

Archived samples of waste and FMPC fly ash (to be used as a stabilization reagent) will be composited at the site prior to conducting the study, as discussed earlier in this work plan.

If the waste material and/or fly ash samples archived are of insufficient volume to complete the study, additional waste material will be obtained from existing drill cuttings, which have been stored in drums at the FMPC site. These drill cuttings are from the additional sampling activities conducted for Operable Unit 2.

7.0 DATA MANAGEMENT

Two types of laboratory notebooks will be used for this project. All laboratory notebooks are uniquely numbered and have sequentially numbered pages (Appendix D).

Project-specific notebooks will be signed out by the facility quality control coordinator (QCC) to the individuals working on the project. All daily laboratory activities associated with the project will be recorded in the project-specific notebooks.

Separate nonproject-specific logbooks will be used to record the injection or introduction of samples into analytical instrumentation. These logbooks are also to be used to record maintenance or problems with instruments (Appendix D).

At the completion of the project, the project-specific laboratory notebooks and logbooks will be returned to the facility QCC for retention. Instrument logbooks will be returned to the facility QCC when the books are filled.

All data will be written into standard laboratory notebooks or onto standard formatted data entry sheets. All records management and reporting will follow standard QA/QC protocol. Standard QA/QC protocol, as it applies to testing within the laboratory, will follow these guidelines:

- One hundred percent verification on all numerical results — All raw data entries, transcriptions, and calculations will be checked and recalculated by the laboratory manager.

- Data verification through test reasonableness — Summaries of all test results for individual reports will be reviewed by the operations supervisor to determine the presence of any data that may be considered as outliers.

- Routine instrument calibration — All instruments, gauges, and equipment used in testing will be calibrated in accordance with the project quality assurance project plan (QAPP).

- Use of trained personnel to conduct tests — All technicians will be trained in the application of standard laboratory procedures for analyses as well as in the QA measures to be implemented for internal QC checks.

8.0 DATA ANALYSIS AND INTERPRETATION

8.1 EFFECTIVENESS OF WASTE FORMS

The results of the leaching tests will be used to evaluate the long-term effectiveness of each waste form. The concentrations of radioactive and hazardous constituents in the leachate will be used as input into the geochemical models described in the RI/FS Work Plan Draft Addendum on risk assessment methodology. These models will be used in conjunction with groundwater fate and transport models to generate data that will then be used to calculate concentrations of contaminants in the aquifer at the location of the RME. These concentrations will, in turn, be used to calculate the magnitude of that exposure and the resulting risks to human health and the environment.

8.2 CEMENT STABILIZATION

For the preliminary screening, Stages I and II, advanced phase testing, the reagent formulation, UCS (where appropriate), reaction temperature, permeability (EPA Method 9100) (when appropriate), shear strength, physical characteristics, and the bulking factor increase will be presented in a tabular format for each test run. The results of the TCLP will also be listed for those mixtures achieving a UCS of approximately 500 psi.

8.3 DATA PRECISION, ACCURACY, AND COMPLETENESS

The following procedures are used to assess data precision, percent recovery, and completeness. Calculations of precision, percent recovery, and completeness will be used to assess data quality.

Example calculations of precision:

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

where

RPD = relative percent difference

C_1 = larger percent difference

C_2 = smaller of the two observed values.

Example of calculation of percent recovery:

$$\%R = \frac{100\% \times (S-U)}{C_{sa}}$$

where

$\%R$ = percent recovery

S = measured concentration in spiked aliquot

U = measured concentration in unspiked aliquot

C_{sa} = actual concentration of spike added.

Example of calculation of completeness:

$$\%C = 100\% \times \frac{V}{n}$$

where

$\%C$ = percent completeness

V = number of measurements judged valid

n = total number of measurements necessary to achieve a specified statistical level of confidence in decision making.

An example of the form used for reporting precision of duplicates and accuracy of spikes is shown in Figure 8-1.

FIGURE 8-1

GENERAL QA/QC REPORT

Analyte:
Matrix:
Sample Number:

Precision of Duplicates
Spike Value (b) =
Spike Dup. Value (a) =

Precision (RPD)

$$\frac{|a-b|}{(a+b)/2} \times 100\% =$$

Accuracy of Spike
Original Value (a) =
Observed Spike Value (b) =
Spike Level (c) =

Accuracy =

$$\frac{b-a}{c} \times 100\% =$$

Accuracy of Spike Dup.
Original Value (a) =
Observed Spike Dup. Value (b) =
Spike Level (c) =

Accuracy =

$$\frac{b-a}{c} \times 100\% =$$

9.0 HEALTH AND SAFETY

See Appendix C for the site-specific health and safety plan.

10.0 RESIDUALS MANAGEMENT

10.1 STABILIZED WASTE

This project will generate approximately 100 kg of cement-stabilized waste. There may also be waste samples that have not undergone treatment that must be handled as residual waste. These residuals will be shipped to the FMPC (currently operated by WEMCO) for disposal. All waste and residual shipments must comply with the provisions of the Federal Treatability Study Sample Exemption Rule (see Section 3.9 of "Guidance for Conducting Treatability Studies Under CERCLA," EPA 1988).

10.2 LEACHATE

As a result of the TCLP, approximately 50 liters of stabilized waste leachate, possibly a RCRA waste, will be generated. This leachate will be sent to the IT Oak Ridge Laboratory in Oak Ridge, Tennessee for analysis and then will be shipped to the FMPC (currently operated by WEMCO) for disposal. All waste and residual shipments must comply with the provisions of the Federal Treatability Study Sample Exemption Rule (see Section 3.9 of "Guidance for Conducting Treatability Studies Under CERCLA," EPA 1988).

All treatability studies will be conducted in accordance with Tennessee's Hazardous Waste Management Regulations for treatability study samples (Tennessee Rule Chapter 1200-1-11-.02-16) and samples undergoing treatability studies at laboratories and testing facilities (Tennessee Rule Chapter 1200-1-11-.02-19).

11.0 REPORTS

An interim draft report will be issued following the completion of the laboratory screening which will document the results of the stabilization and extraction procedures. This report will identify those reagent combinations that yielded the best results and may recommend further testing for later treatability studies. In addition, all raw data will be presented in a tabular format.

The final report for the laboratory screening will be issued after reviews by concerned organizations have been completed. The following outline can be used as a guide when preparing the reports.

SUGGESTED ORGANIZATION OF TREATABILITY STUDY REPORT

1.0 Introduction
- 1.1 Site description
  - 1.1.1 Site name and location
  - 1.1.2 History of operations
  - 1.1.3 Prior removal and remediation activities
- 1.2 Waste stream description
  - 1.2.1 Waste matrices
  - 1.2.2 Pollutants/chemicals
- 1.3 Remedial technology description
  - 1.3.1 Treatment process and scale
  - 1.3.2 Operating features
- 1.4 Previous treatability studies at the site

2.0 Conclusions and Recommendations
- 2.1 Conclusions
- 2.2 Recommendations

3.0 Treatability Study Approach
- 3.1 Test objectives and rationale
- 3.2 Experimental design and procedures
- 3.3 Equipment and materials
- 3.4 Sampling and analysis
  - 3.4.1 Waste stream
  - 3.4.2 Treatment process
- 3.5 Data management
- 3.6 Deviations

4.0 Results and Discussion 1
4.1 Data analysis and interpretation 2
4.1.1 Analysis of waste stream characteristics 3
4.1.2 Analysis of treatability 4
4.1.3 Comparison to test objectives 5
4.2 Quality assurance/quality control 6
4.3 Costs/schedule for performing the treatability study 7
4.4 Key contacts 8
References 9
Appendices 10
A. Data summaries 11
B. Standard operating procedures 12

12.0 COMMUNITY RELATIONS

Treatability studies and community information and involvement activities are required in the CERCLA process. Community relations activities shall be conducted: (1) to support treatability studies for Operable Unit 2 to explain the role of treatability studies in the RI/FS and (2) to raise the public's confidence in cleanup alternatives and technologies identified in the alternatives screening/analysis process and in the preferred alternative for this operable unit. The treatability study community relations activities for Operable Unit 2 will comply with the Community Relations Plan — "Remedial Investigation/Feasibility Study and Removal Actions at the U.S. Department of Energy Feed Materials Production Center, Fernald, Ohio," August 1990. At a minimum, the following community relations activities will be conducted to explain treatability studies for Operable Unit 2.

- Community Meetings—Held a minimum of three times per year to provide status on cleanup issues, and to ensure that interested area residents have a routine public forum for receiving new information, expressing their views, and getting answers to their questions, the meetings will focus on operable unit updates, removal actions, major RI/FS documents, and other appropriate topics.

- Publications—RI/FS materials such as progress reports, factsheets, a community newsletter *(Fernald Site Cleanup Report)*, and updates of CERCLA-related activities at the FMPC will include information on treatability study activities for this operable unit.

- Presentations to Community Groups—Information about treatability studies for this operable unit will be included in briefings to community groups in Ross, Crosby, and Morgan townships, and to Fernald Residents for Environment Safety and Health, as appropriate. Also, this information will be included in presentations to other organizations, as requested.

Key milestones in treatability studies will be identified and progress reported to the community in these presentations and publications. These milestones include:

- Submittal of the work plan to DOE and EPA
- EPA approval of the work plan
- Treatability testing
- Submittal of the treatability study report

Other activities identified in Section 4.0 of the Community Relations Plan may be utilized as appropriate to effectively communicate treatability information to the community. Such activities may include workshops and community roundtables.

13.0 MANAGEMENT AND STAFFING

The project organization for this treatability testing is shown in Figure 13-1.

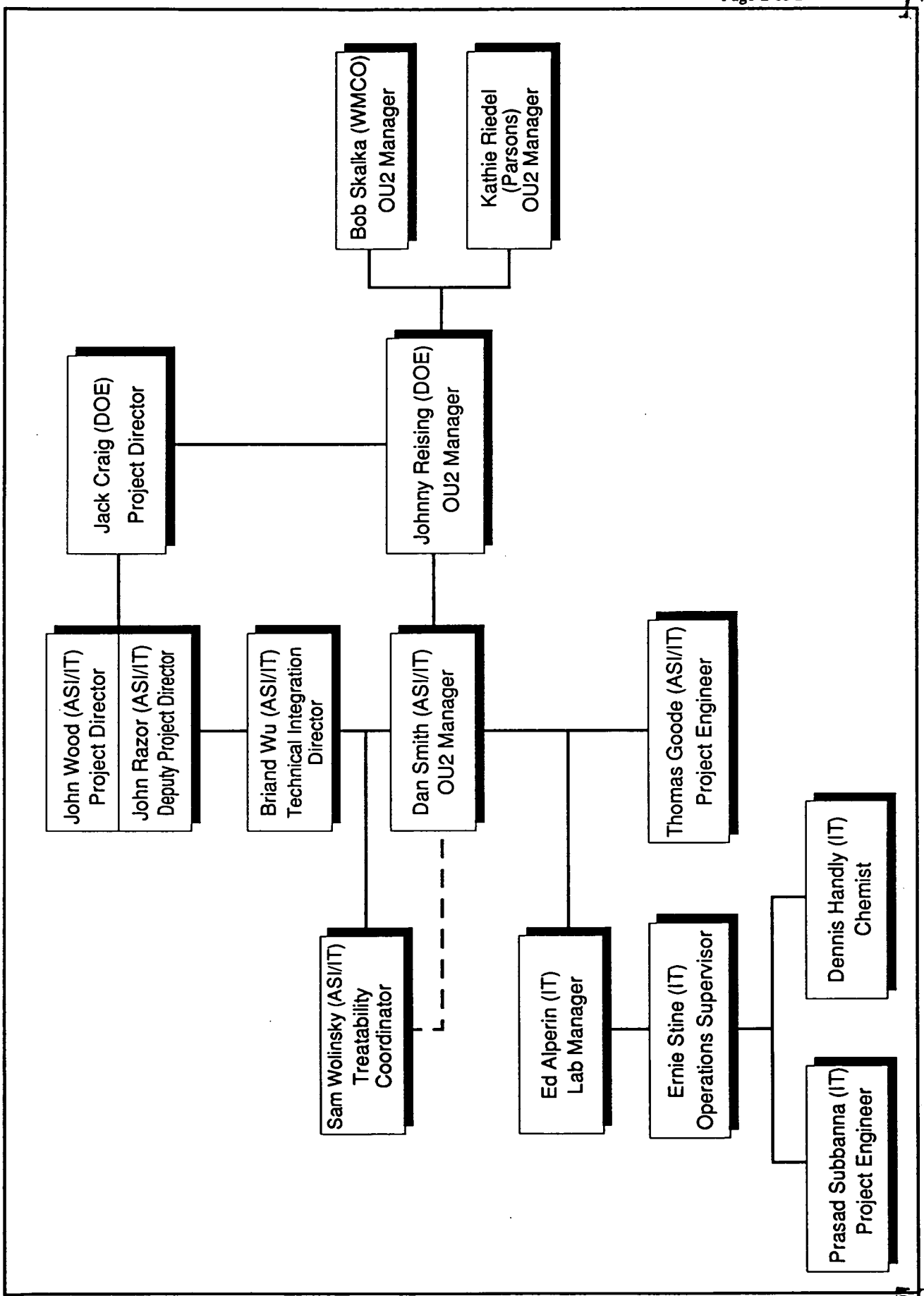

Figure 13-1. Management and Staffing.

REFERENCES

LIST OF REFERENCES

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APPENDIX A

SOLIDIFICATION AS A TREATMENT OPTION FOR OPERABLE UNIT 2 WASTES

A.1.0 INTRODUCTION

The purpose of this Appendix is to provide additional justification for choosing stabilization/solidification using a portland cement/fly ash mixture as the treatment process option to treat the lime sludge, the Southfield waste, and the resultant ash from incinerating the Sanitary Landfill waste. The wastes would be solidified using the fly ash from the Active Fly Ash Pile, although solidification using fly ash from the Inactive Fly Ash Disposal Area also will be examined on a limited basis.

The additional justification will be provided by discussing results from a literature search of solidification technology. The literature search provides information which indicates that solidification of the wastes will provide a waste form that could pass extraction procedure (EP) toxicity leach tests and allow mixed wastes to be disposed of as nonhazardous or low-level wastes. Also discussed in this Appendix will be the reasoning for using the cement to fly ash ratios and water to cement ratios indicated in Section 4.0 and the justification for using an unconfined compressive strength (UCS) of approximately 500 psi.

A.2.0 LITERATURE SEARCH

A.2.1 TYPES OF SOLIDIFICATION

Various solidification processes exist which could be used to solidify waste. Systems which could be used for solidification are the portland cement-based process, the portland cement/soluble silicate process, the lime/fly ash-based systems, the kiln dust and fly ash-based process, and the portland cement/fly ash process.

A.2.1.1 Portland Cement-Based Process

With the portland cement process, water in the waste reacts chemically with the cement to form a hardened concrete-like material. Depending upon the amount of cement added, the final product may be a monolithic solid or may have a crumbly soil-like consistency (EPA 1985). The optimum combination of waste, water, and portland cement will vary with waste type and composition. The minimum water to cement ratio is about 0.40, by weight, for portland cement, but this also depends upon the moisture content of the waste. The addition of too much water may result in free-standing water on the surface of the solidified product, as well as a reduction in its strength and an increase in the permeability of the final product (Conner 1990).

The bulk density of cement-based waste forms varies between 1.25 and 1.75 g/cm^3, with water contents ranging from about 15 to 60 percent. The UCS varies also, depending upon the mix ratio.

Most products range from 15 to 1000 psi but can be strengthened by other additives. Permeability is influenced by solidification of the waste. The permeability of cement-based waste forms is similar to that of clay (Conner 1990).

The chemical properties of cement-based forms are described in terms of leachability. The interaction of organic and inorganic substances in cement affects the setting and hardening of the cement matrix. Salts of manganese, tin, zinc, copper, and lead tend to reduce the strength of the waste form. Cement solidification can immobilize metals; but if the waste form is subjected to even a mild acidic solution, leaching could take place (EPA 1985). Because of these limitations, portland cement is normally used as a setting agent in combination with other solidification processes.

The cost of the portland cement-based process is low and the equipment for the process is readily available.

A.2.1.2 Portland Cement/Soluble Silicate (PCSS) Processes

The PCSS process is based on the reactions between soluble silicates and portland cement to produce a solid matrix. This process is dependent upon three different reactions, the first being a rapid reaction between the soluble silicate (such as sodium silicate) and metal ions to produce a low-solubility metal silicate. The second set of reactions occurs between the soluble silicate and the portland cement. The third set of reactions occur among the cement, waste, and water. The soluble silicate functions as a surfactant (keeping retarders such as oil or particulates in suspension), which helps in the setting and hardening of the waste.

By adding soluble silicate to the portland cement, low-solid waste can be solidified without the addition of massive amounts of bulking agents. This is a cost-effective approach; but the water content of the waste form is high, and this increases the porosity of the solid. Higher water content also causes reduced strength and higher permeability. The UCS ranges between 15 and 100 psi, but stronger products can be prepared (with the addition of cement). The advantages of this process include relative low cost and small volume increase; however, the UCS is lower than the 500 psi proposed by the Nuclear Regulatory Commission (NRC 1991) and discussed in Section A.3.0 of this appendix.

A.2.1.3 Lime/Fly Ash-Based Process

Combining lime and fly ash with water forms a cementitious material. Initially a noncrystalline gel, which eventually becomes a calcium silicate hydrate, is formed. The reactions which occur are similar to cement-based systems. However, the reactions are slower and do not produce the same products as the cement-based system in terms of physical and chemical properties. A problem with the lime/fly ash process is that fly ash is a by-product of coal-burning power plants and its composition depends

upon the type of coal burned and how the plant was operated. Unburned organics in the fly ash can reduce the cementing action by covering reactive surfaces. Also, the lime-based process is not as effective in reducing leachability as the cement-based systems, due in part to its high pH. Much lime/fly ash treatment used has been in nonhazardous waste applications.

A.2.1.4 Kiln Dust and Fly Ash-Based Process

Kiln dust and fly ash have been used in several solidification projects. They function primarily as absorbents or bulking agents. The kiln dusts are highly alkaline, which gives them the ability to remove free water by hydration of calcium oxide to calcium hydroxide. This process can produce hard, strong solids that continue to harden with time. The actual setting reactions of the kiln dust and fly ash are pozzolanic and resemble those of portland cement. A limitation on the use of these materials is that they contain significant amounts of metals, which leach at levels above regulatory standards. These materials are available, and their costs are low compared to portland cement. However, the cost of these materials has been increasing; if the trend continues, they could be replaced by more expensive but more efficient reagents (Conner 1990).

A.2.1.5 Portland Cement/Fly Ash Process

Portland cement and fly ash have been used in applications for many years. When fly ash is used with cement in an application, the percentage of cement required is reduced significantly. Since fly ash itself is a waste, it is desirable to use it as a component in solidification systems.

Fly ash in portland cement acts as a bulking agent and as a pozzolan. The reaction between the two materials produces a product that may have higher strength than when portland cement is used alone. The fly ash also helps to bind additional water and decrease pH, as well as acting as an adsorbent for metal ions. The greatest disadvantage of this process is the volume increase associated with large additions of fly ash. The range of the fly ash to cement ratio (by weight) is two to four, with total weight increases of 50 to 150 percent. Where increase in volume is not important, the cement/fly ash process is the optimum choice (Conner 1990).

In a pure water-cement system, the permeability is essentially zero at a water to cement ratio of 0.32. The water to cement ratio can be increased when a bulking agent such as fly ash is added to the process.

Several vendors use the cement/fly ash process and many studies have been performed. One such program was performed on waste at the Idaho National Engineering Laboratory (INEL).

A.2.2 INEL STUDIES

The Waste Engineering Development group of EG&G Idaho (the operating contractor), in an effort to develop a safe, cost-effective method for treating hazardous and mixed wastes, initiated a program to investigate (1) treatment options available for the various hazardous and mixed wastes at INEL, (2) available commercial solidification methods and their applicability to INEL wastes, (3) lab-scale testing of solidification methods for developing waste formulas, and (4) testing solidified waste samples to verify that they pass EP toxicity criteria. The program intent was to provide a treatment method that would result in a nonhazardous stable waste form that would satisfy EPA regulations.

Two of the wastes that were inventoried and characterized as containing hazardous constituents were fly ash that was collected in the baghouse of the Waste Experimental Reduction Facility (WERF) during incineration operations and incinerator ash that is bottom ash generated from operation of the WERF incinerator. Analysis of the baghouse fly ash indicated the hazardous constituents in the waste to be cadmium and lead. Solidification was recommended as the proposed treatment option. The incinerator ash contained a lead concentration that was above the EP toxic limit for lead. Solidification also was recommended as the proposed treatment method for the incinerator ash, to bind the hazardous constituent and immobilize the radioactive constituents (Boehmer 1986).

According to Boehmer's conclusions, solidification processing is the best method of disposition available for EP toxic or corrosive wastes with metal contents in excess of the limits. The reason for this is that the solidification process chemically binds the metals in the cement matrix and prevents them from leaching out of the solidified waste monolith, enabling the waste form to pass leach tests. Solidification processing also provides a stable waste form for disposal. Once the solidified waste has passed the leach tests, it can be disposed of as a nonhazardous or low-level radioactive waste, depending on its radioactivity.

After proposing solidification as the method to treat the fly ash, an investigation of available commercial solidification methods was performed. It was determined that the most suitable systems for INEL wastes were the Delaware Custom Material cement-silicate and United States Gypsum Company's ENVIROSTONE. These two systems were chosen because they could be used very effectively for processing small volumes of waste and could provide acceptable waste monoliths for a variety of waste streams. These two systems were also chosen for their short implementation time, ease of operability, and cost-effectiveness.

The next phase of the program involved lab-scale testing of actual waste samples to determine or develop optimum binder-to-waste ratios. Lab-scale testing was conducted on the baghouse dust using various combinations of cement, silicate, ENVIROSTONE, and water.

The results of the fly ash testing showed that successful solidification required 30 grams of cement per 50 grams of fly ash with a minimum of 100 mℓ of water.

Addition of the silicate to the cement tended to reduce the amount of lead that leached from the sample. Silicate alone, however, had no effect on the leach rates of any of the three contaminants. A successful solidification of the fly ash using the ENVIROSTONE binder was not obtained.

The results of the fly ash testing have shown that the fly ash can be successfully solidified using water and cement or the potassium-chromate solution with the cement-silicate binders. This will provide a safe, efficient, cost-effective treatment method for long-term disposal of the fly ash waste (Boehmer and Larsen 1986).

A.2.3 SOLIDIFICATION PROCESS CHOSEN FOR OPERABLE UNIT 2

The portland cement/fly ash process is the technology that has been chosen to solidify the wastes in Operable Unit 2. Since fly ash in the Active Fly Ash Pile is a waste, it can be used as a resource to aid in solidifying other wastes. As stated in Section A.2.1.5, the portland cement/fly ash process produces a solidified product that has a higher UCS than that of the product when portland cement is used alone. The water to cement ratio of 0.32 and the portland cement to fly ash ratio of 2 have been used in formulating the tables in Section 4.0.

A.3.0 JUSTIFICATION OF UCS

An objective of the treatability study is to provide a waste form that possesses a UCS of approximately 500 psi. The 500 psi UCS is one that has been recommended by the NRC in a technical position paper and is stated as follows:

> Portland cement mortars, which are comprised of mixtures of cement, lime, silica sand and water, are readily capable of achieving compressive strengths of 5000 to 6000 psi; that is approximately two orders of magnitude greater than the minimum compressive strength required to resist deformation under load in current low-level waste burial trenches. Therefore, to provide greater assurance that there will be sufficient cementitious material present in the waste form to not only withstand the burial loads, but also to maintain general "dimensions and form" (i.e., to not disintegrate) over time, it is recommended that cement-stabilized waste forms possess compressive strengths that are representative of the values that are reasonably achievable with current cement solidification processes. Taking into consideration the fact that low-level radioactive waste material constituents are not in most cases capable of providing the physical and chemical functions of silica sand in a cement mortar, a mean compressive strength equal to or greater than 500 psi is recommended for waste form specimens cured for a minimum of 28 days (see Section III.B of Appendix A). This value of compressive strength is recommended as a practical strength value that is representative of the

quality of cementitious material that should be used in the waste form to provide assurance that it will maintain integrity and thus possess the long term structural capability required by Part 61 (NRC 1991).

APPENDIX A
REFERENCES

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APPENDIX B

OPERABLE UNIT 2 WASTE CHARACTERISTICS

TABLE B-1

OPERABLE UNIT 2 - SANITARY LANDFILL CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
1.	Area	42,300 ft^2 (1 acre)	A soil cover exists over the area.
2.	Contents: Nonburnable, nonradioactive sanitary wastes generated on property (20 yd^3/wk), double-bagged and bulk quantities of nonradioactive asbestos, radioactive contaminated construction rubble and soils.	Volume of waste 16,000 to 18,000 yd^3	References 1 and 2 5 full cells and an area adjacent to the cells used to dispose of waste.
3.	Surface Water	None	
4.	Data from geotechnical evaluation		Reference 3
	(a) Specific gravity	2.57 to 2.58	
	(b) Moisture content[b]	17.8%	
	(c) Maximum dry density	100.2 to 114 ft^3	
5.	Material consistency	52 to 60% of particles smaller than 74 µm	Reference 2 Per ASTMD[c]422, silt-sized particles are defined in 5 to 74 µm range
6.	Radioactive materials		
	Uranium-238	12 to 35 pCi/g	All other radionuclide concentrations were below background levels. (References 1 and 2)
	Uranium-235	0.4 to 1.4 pCi/g	
	Uranium-234	4.9 to 28.0 pCi/g	
	Plutonium-238	0.1 pCi/g	
7.	Volatile Inorganics		Detected quantities of arsenic and mercury are below available background levels. (References 1 and 2)
	Arsenic (As)	3.28 to 6.69 mg/kg	
	Mercury (Hg)	0.14 to 0.20 mg/kg	

TABLE B-1 (Continued)

OPERABLE UNIT 2 - SANITARY LANDFILL CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
8.	Organics		References 1 and 2
	PCBs (Aroclors 1242, 1248, and 1254)	78 to 1600 µg/kg	
	2-Methylnaphthalene	66 to 11,000 µg/kg	
	Xylenes (volatile)	320 µg/kg	
9.	HSL Volatiles		
	Acetone	12 to 25 µg/kg	
	2-Butanone	120 µg/kg	
	Ethyl Benzene	91 µg/kg	
	Methylene Chloride	8 to 160 µg/kg	
	Tetrachloroethene	97 µg/kg	
	Toluene	180 µg/kg	
	Chloroform	9 to 13 µg/kg	
	1,1,1 Trichloroethane	5 to 6 µg/kg	
10.	HSL Semivolatiles		References 1 and 2
	Chrysene	170 to 4,600 µg/kg	
	Acenaphthene	1,300 to 28,000 µg/kg	
	Anthracene	85 to 2,800 µg/kg	
	Benzo(a)anthracene	130 to 5,100 µg/kg	
	Benzo(a)pyrene	100 to 7,000 µg/kg	
	Benzo(b)fluoranthene	98 to 6,700 µg/kg	
	Benzo(g,h,i)perylene	110 to 6,000 µg/kg	
	Benzo(k)fluoranthene	84 to 4,900 µg/kg	
	Dibenzo(a,h)anthracene	560 to 2,100 µg/kg	
	Fluoranthene	330 to 450 µg/kg	
	Fluorene	1,400 to 2,500 µg/kg	
	Indeno(1,2,3-cd)pyrene	81 to 5,700 µg/kg	
	Naphthalene	2,700 to 19,000 µg/kg	
	Phenanthrene	320 to 330 µg/kg	
	Pyrene	240 to 6,300 µg/kg	
	bis(2-ethylhexyl)phthalate	49 to 150 µg/kg	
	Butyl benzylphthalate	320 µg/kg	

TABLE B-1 (Continued)

OPERABLE UNIT 2 - SANITARY LANDFILL CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
10.	HSL Semivolatiles (continued)		
	Dibenzofuran	620 to 1,900 µg/kg	
	2,4-Dimethylphenol	240 µg/kg	
	Di-n-butyl phthalate	55 to 330 µg/kg	
	Di-n-octyl phthalate	300 to 350 µg/kg	
	2-Methylphenol	96 µg/kg	
	4-Methylphenol	360 µg/kg	
	N-nitrosodiphenylamine	67 µg/kg	
	Phenol	310 µg/kg	
11.	HSL Inorganics		All other inorganic
	Cadmium	1.92 to 5.33 mg/kg	concencrations were below
	Nickel	12.73 to 42.35 mg/kg	background levels.
	Zinc	39.61 to 166.7 mg/kg	(References 1 and 2)

[a] References:

1. Weston, Roy F., November 1987b. "Characterization Investigation Study Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits," U.S. Dept of Energy Feed Materials Production Center, Fernald, OH, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

2. U.S. Dept of Energy, 1988b. "FMPC Sampling and Analysis Report," 2 Vols., Draft, DOE, Oak Ridge Operations Office, Oak Ridge, TN.

3. Weston, Roy F., March 1988. "Geotechnical Evaluation of Material Properties of Waste Pit Materials at the Feed Materials Production Center, Fernald, Ohio," prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

[b] By percent of total dry weight

[c] American Society for Testing Materials

TABLE B-2

OPERABLE UNIT 2 - NORTH AND SOUTH LIME SLUDGE POND CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
1.	Area: Approximate dimensions in ft 150 x 250 x 11.5 deep (South Pond) 150 x 250 x 5 to 7 deep (North Pond)	 29,600 ft^2 (South Pond) 28,000 ft^2 (North Pond)	
2.	Contents: Spent lime, lime-alum sludge and boiler plant blowdown	5,000 yd^3 (North Pond) 11,500 yd^3 (South Pond)	References 1 and 2 North Pond is approximately 90% full. The South Pond was reactivated recently and currently receives spent lime sludge.
3.	Surface water		
	North Pond: Water depth ranging from 1 to 7 ft	150,000 gal. (maximum)	
	South Pond	None	
4.	Data from geotechnical evaluation		Reference 3
	Specific gravity Moisture content[b] Maximum dry density	2.33 to 2.49 38.8 to 134% 72.8 lbs/ft^3	
5.	Material consistency: Nonplastic silty-clayey type material	94 to 99% of particles smaller than 74 µm	Per ASTM[c]422, silt-sized particles are defined in the 5 - 74 µm range.
		10.5 to 16.7% of particles smaller than 5 µm	Per ASTMD422, this size designation defines the beginning of clay and colloid particle range.

OPERABLE UNIT 2 - NORTH AND SOUTH LIME SLUDGE POND CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
6.	Radioactive materials		All other radionuclide concentrations were below background levels. (References 1 and 2)
	North Pond		
	Strontium-90	2.20 pCi/g	
	Thorium-230	0.5 to 20.0 pCi/g	
	Uranium-234	2.1 to 2.5 pCi/g	
	Uranium-235	0.1 to 0.2 pCi/g	
	Uranium-238	2.4 to 7.6 pCi/g	
	South Pond		
	Thorium-230	0.9 to 7.0 pCi/g	
	Thorium-232		
	Uranium-234	1.8 to 3.1 pCi/g	
	Uranium-235	0.1 to 0.3 pCi/g	
	Uranium-238	2.2 to 2.8 pCi/g	
7.	Volatile Inorganics		References 1 and 2
	Arsenic (As)	6.3 to 16.0 mg/kg	North Pond Only. South Pond data indicates no As and Hg present.
	Mercury (Hg)	0.30 mg/kg	
8.	Organics		References 1 and 2
	North Pond		
	Chlordane	1,200 µg/kg	
	PCBs (Aroclor 1248)	1,200 µg/kg	
9.	HSL Volatiles		References 1 and 2
	North Pond		
	Acetone	20 to 150 µg/kg	
	Carbon disulfide	7 to 9 µg/kg	
	1,1-dichloroethane	30 µg/kg	
	Methylene Chloride	21 to 26 µg/kg	
	1,1,2-Trichloro-1,2,2-Trifluoroethane	50 to 81 µg/kg	
	Toluene	20 µg/kg	

TABLE B-2 (Continued)

OPERABLE UNIT 2 - NORTH AND SOUTH LIME SLUDGE POND CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
9.	HSL Volatiles (continued)		
	South Pond		
	Acetone	18 to 140 µg/kg	
	2-Butanone	1800 µg/kg	
	Methylene Chloride	110 to 240 µg/kg	
	Chloroform	7 to 11 µg/kg	
	1,1,1-Trichloroethane	9 to 14 µg/kg	
10.	HSL Semivolatiles		References 1 and 2
	North Pond		
	bis(2-ethylhexyl)phthalate	100 to 310 µg/kg	
	Butyl Benzyl Phthalate	370 to 2,800 µg/kg	
	Di-n-butyl Phthalate	89 to 330 µg/kg	
	Phenol	61 µg/kg	
	South Pond		
	Benzoic Acid	160 µg/kg	
	bis(2-ethylhexyl)phthalate	230 to 310 µg/kg	
	Di-n-butyl Phthalate	47 to 73 µg/kg	
	Phenol	89 µg/kg	
11.	HSL inorganic		
	Zinc	38 to 75 mg/kg	North Pond Only. All other inorganic concentrations were below background levels. (References 1 and 2)

[a] References:

1. Weston, Roy F., November 1987b. "Characterization Investigation Study Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits," U.S. Dept of Energy Feed Materials Production Center, Fernald, OH, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.
2. U.S. Dept of Energy, 1988b. "FMPC Sampling and Analysis Report," 2 Vols., Draft, DOE Oak Ridge Operations Office, Oak Ridge, TN.
3. Weston, Roy F., March 1988. "Geotechnical Evaluation of Material Properties of Waste Pit Materials at the Feed Materials Production Center, Fernald, Ohio," prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

[b] By percent of total dry weight

[c] American Society for Testing Materials

TABLE B-3

OPERABLE UNIT 2 - ACTIVE FLY ASH PILE CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
1.	Area	93,800 ft^2 (2.2 acres)	
2.	Contents: Fly Ash	38,000 yd^3	
3.	Surface water	None	
4.	Data from geotechnical evaluation	None	Reference 3
5.	Material consistency		No geotechnical information or visual classification available.
6.	Radioactive materials		All other radionuclide concentrations were below background levels. (References 1 and 2) Elevated levels of uranium from waste oil sprayed for dust control.
	Lead-210	4.0 pCi/g	
	Radium-226	0.4 to 2.4 pCi/g	
	Radium-228	0.1 to 2.2 pCi/g	
	Thorium-228	0.7 to 52.0 pCi/g	
	Thorium-230	4.5 to 41.0 pCi/g	
	Uranium-234	0.1 to 4.9 pCi/g	
	Uranium-235	2.2 to 253.0 pCi/g	
	Uranium-238		
7.	Volatile Inorganics	Analysis not performed	References 1 and 2
8.	Organics	Analysis not performed	References 1 and 2
9.	HSL Volatiles		References 1 and 2
	Acetone	37 to 940 µg/kg	
	2-Butanone	29 to 67 µg/kg	
	Chloroform	6 to 11 µg/kg	
	Methylene Chloride	160 to 1,100 µg/kg	
	1,1,1-Trichloroethane	19 to 420 µg/kg	
	Toluene	19 to 89 µg/kg	

TABLE B-3 (Continued)

OPERABLE UNIT 2 - ACTIVE FLY ASH PILE CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
10.	HSL Semivolatiles	Analysis not performed	References 1 and 2
11.	HSL Inorganics	Analysis not performed	References 1 and 2

[a] References:

1. Weston, Roy F., November 1987b. "Characterization Investigation Study Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits," U.S. Dept of Energy Feed Materials Production Center, Fernald, OH, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

2. U.S. Dept of Energy, 1988b. "FMPC Sampling and Analysis Report," 2 Vols., Draft, DOE Oak Ridge Operations Office, Oak Ridge, TN.

3. Weston, Roy F., March 1988. "Geotechnical Evaluation of Material Properties of Waste Pit Materials at the Feed Materials Production Center, Fernald, Ohio," prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

TABLE B-4

OPERABLE UNIT 2 - INACTIVE FLY ASH DISPOSAL AREA

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
1.	Area	131,000 ft^2 (3 acres)	
2.	Contents: fly ash and building rubble	50,000 yd^3	
3.	Surface water	None	
4.	Data from geotechnical evaluation	None	Reference 3
5.	Material consistency: High to low plasticity clays intermixed with sand-sized particles and fly ash.		Reference 3 Visual Classification
6.	Radioactive materials		References 1 and 2 Elevated levels of uranium from waste oil sprayed for dust control.
	Lead-210	2.0 to 5.0 pCi/g	
	Radium-226	0.6 to 4.1 pCi/g	
	Radium-228	1.7 to 2.0 pCi/g	
	Thorium-228	0.2 to 2.3 pCi/g	
	Thorium-230	0.2 to 11.0 pCi/g	
	Thorium-232	0.1 to 2.6 pCi/g	
	Uranium-234	3.7 to 48.0 pCi/g	
	Uranium-235	0.2 to 2.2 pCi/g	
	Uranium-238	6.6 to 50.0 pCi/g	
7.	Volatile Organics		References 1 and 2 Detected quantities of arsenic are below available background levels.
	Arsenic (As)	5.91 to 10.76 mg/kg	
	Mercury (Hg)	0.139 to 0.26 mg/kg	

TABLE B-4 (Continued)

OPERABLE UNIT 2 - INACTIVE FLY ASH DISPOSAL AREA

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
8.	Organics PCBs (Aroclors 1242, 1254, and 1260)	5.70 µg/kg to 290.0 µg/kg	References 1 and 2
9.	HSL Volatiles	Analyzed for, but not detected	References 1 and 2
10.	HSL Semivolatiles	Analyzed for, but not detected	References 1 and 2
11.	HSL Inorganics Cadmium Lead	 2.43 to 3.82 mg/kg 13.8 to 56.0 mg/kg	All other inorganic concentrations were below background concentrations. (References 1 and 2)

[a] References:

1. Weston, Roy F., November 1987b. "Characterization Investigation Study Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits," U.S. Dept of Energy Feed Materials Production Center, Fernald, OH, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

2. U.S. Dept of Energy, 1988b. "FMPC Sampling and Analysis Report," 2 Vols., Draft, DOE Oak Ridge Operations Office, Oak Ridge, TN.

3. Weston, Roy F., March 1988. "Geotechnical Evaluation of Material Properties of Waste Pit Materials at the Feed Materials Production Center, Fernald, Ohio," prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

TABLE B-5

OPERABLE UNIT 2 - SOUTHFIELD CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
1.	Area	455,000 ft^2 (10.4 acres)	
2.	Contents: Soils and construction rubble containing low levels of radioactivity.	125,000 yd^3	
3.	Surface Water	None	
4.	Data from geotechnical evaluation	None	Reference 3
5.	Material Consistency: Construction rubble intermixed with native clay fill		Reference 3 Visual Classification
6.	Radioactive Materials		All other radionuclide concentrations were below background levels. (References 1 and 2)
	Lead-210	2.0 to 28 pCi/g	
	Cesium-137	0.3 pCi/g	
	Radium-226	0.4 to 266.0 pCi/g	
	Radium-228	0.6 to 10 pCi/g	
	Thorium-228	0.1 to 129 pCi/g	
	Thorium-230	0.1 to 1,070 pCi/g	
	Thorium-232	0.1 to 130 pCi/g	
	Uranium-234	2.0 to 11,400 pCi/g	
	Uranium-235	0.09 to 5.8 pCi/g	
	Uranium-238	2.0 to 8,600 pCi/g	
7.	Volatile Inorganics		Detected quantities of Arsenic are below available background levels. (References 1, 2, and 4)
	Arsenic (As)	3.7 to 8.1 mg/kg	
	Mercury (Hg)	0.121 to 1.22 mg/kg	

TABLE B-5 (Continued)

OPERABLE UNIT 2 - SOUTHFIELD CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
8.	Organics		References 1, 2, and 4
	PCBs (Aroclors 1242, 1254, and 1260)	1.9 to 1100 µg/kg	
9.	HSL Volatiles		References 1, 2, and 4
	Acetone	3 to 180 µg/kg	
	2-Butanone	4 to 42 µg/kg	
	Chloroform	2 to 10 µg/kg	
	Methylene chloride	2 to 280 µg/kg	
	Toluene	1 to 26 µg/kg	
10.	HSL Semivolatiles		Reference 4
	Fluoranthene	39 to 300 µg/kg	
	Pyrene	43 to 270 µg/kg	
	Phenanthrene	110 µg/kg	
	Benzo(a)anthracene	170 µg/kg	
	Chrysene	170 µg/kg	
	Benzo(b)fluoranthene	290 µg/kg	
	Benzo(a)pyrene	230 µg/kg	
	Bis(2-Ethylhexyl)phthalate	40 µg/kg	
11.	HSL Inorganics	2.12 to 5.15 mg/kg	References 1, 2, and 4
	Cadmium	9.76 to 27.7 mg/kg	All other inorganic
	Cobalt	10.4 to 34 mg/kg	concentrations were below
	Lead	10.2 to 48.3 mg/kg	background concentrations
	Nickel		(References 1 and 2.)
	Beryllium	1.2 to 1.5 mg/kg	Reference 4
	Calcium	12,100 to 126,000 mg/kg	(These inorganic concentrations
	Copper	9.7 to 24.3 mg/kg	were above background
	Iron	15,900 to 25,900 mg/kg	concentrations listed in
			Reference 5)

TABLE B-5 (Continued)

OPERABLE UNIT 2 - SOUTHFIELD CHARACTERISTICS

Item No.	Description	Quantities (Approximate) and Units	References[a] and/or Comments
11.	HSL Inorganics		Reference 4
	Magnesium	6,000 to 24,800 mg/kg	(These inorganic concentrations
	Manganese	323 to 823 mg/kg	were above background
	Zinc	41 to 66.3 mg/kg	concentrations listed in
	Potassium	548 to 866 mg/kg	Reference 5)

[a] References:

1. Weston, Roy F., November 1987b. "Characterization Investigation Study Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits," U.S. Dept of Energy Feed Materials Production Center, Fernald, OH, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

2. U.S. Dept of Energy, 1988b. "FMPC Sampling and Analysis Report," 2 Vols., Draft, DOE Oak Ridge Operations Office, Oak Ridge, TN.

3. Weston, Roy F., March 1988. "Geotechnical Evaluation of Material Properties of Waste Pit Materials at the Feed Materials Production Center, Fernald, Ohio," prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

4. IT, 1990. Certificate of Analysis, January 9 through 15, Sampling Locations 55906, 55919, 55945, 55959, and 55972, International Technology Corporation, Analytical Services, Knoxville, TN.

5. U.S. Geological Survey Data for the Eastern United States (Shacklette and Boerngen 1984).

APPENDIX C

HEALTH AND SAFETY PLAN
FOR THE
FEED MATERIALS PRODUCTION CENTER
OPERABLE UNIT 2
TREATABILITY PROGRAM LABORATORY SCREENING
PROJECT NUMBER 303317.22.05.01

APPENDIX C
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C.1.0 INTRODUCTION

This Health and Safety Plan (HSP) establishes the work practices necessary to help ensure protection of IT Corporation (IT) personnel during the Operable Unit 2 (OU2) laboratory screening to be performed at IT's Environmental Technology Development Center (ETDC) Laboratory in Oak Ridge, Tennessee.

The objective of this plan is to provide a mechanism for the establishment of safe and healthy working conditions at the laboratory. The safety procedures that have been established are based on analyses of potential hazards at the laboratory, and procedures have been developed to minimize the potential for accident or injury.

All laboratory operations will be performed in accordance with applicable state and local regulations, IT corporate procedures and Occupational Safety and Health Administration (OSHA) requirements.

C.1.1 SCOPE OF WORK

This laboratory screening will involve mixing Operable Unit 2 waste samples with various reagents to conduct cement stabilization. Sanitary Landfill samples will be heated in a lab furnace up to 1200°C prior to stabilization. The stabilized wastes will then be tested for compressive strength using a pocket penetrometer (Soiltest CT-421) and the unconfined compressive strength (UCS) method (ASTMD2166) using a Soiltest U-590. Following compressive strength testing, the wasteforms will be tested for leaching characteristics using the Modified Toxicity Characteristics Leaching Procedure (MTCLP) test, a full TCLP test. All testing will be performed at IT's ETDC Laboratory. The samples for this treatability study will be drawn under the Operable Unit 2 Sampling and Analysis Plan (SAP).

C.1.1.1 Preliminary Characterization

The samples drawn under the Operable Unit 2 SAP will be composited and analyzed at the IT Oak Ridge Laboratory in Oak Ridge, Tennessee. These activities will be governed by the Health and Safety Plan for the SAP.

C.1.1.2 Cement Stabilization

The cement stabilization laboratory screening will consist of mixing cement stabilization reagents (Portland cement, fly ash, sodium silicate, attapulgite, clinoptiloite, and water) in varying quantities with waste material. These stabilization reagents will be mixed with 100 grams of composited waste in a graduated plastic cup. Mixing will be performed by hand in a laboratory hood with a spatula until the mixture is homogeneous (approximately 2 minutes). After a prescribed setting period the stabilized wastes will be tested for compressive strength and leachability characteristics.

C.2.0 RESPONSIBILITIES

The following list explains which personnel are responsible for various activities in the HSP and what their responsibilities are.

- ETDC Health and Safety (H&S) Officer (Keith Hood) – Responsible for the technical development and coordination of the HSP. Inquiries regarding the HSP, IT Corporate H&S Procedures, and other technical or regulatory items shall be addressed to the Health and Safety Officer.

- Laboratory Project Supervisor (Ernie Stine) – Responsible for implementation of the HSP. This shall include communication of requirements to all personnel and interaction with client representatives and regulatory agencies. Additional communication may include consultation with the H&S Manager regarding the execution of the project and the HSP.

- Laboratory personnel–Responsible for understanding and complying with all site H&S requirements. Each team member shall receive training on the requirements of this HSP prior to the beginning of the project.

- Emergency coordinators (Tom Geisler, Rick Greene) – Responsible for and having the full authority to commit any personnel or equipment necessary for response and recovery operations during spills, disasters, or other emergencies.

C.3.0 SITE HISTORY

A variety of chemical and metallurgical processes were utilized at the Feed Materials Production Center (FMPC) for the manufacture of uranium products. During the manufacturing process, high quality uranium compounds were introduced into the FMPC processes at several points. Impure starting materials were dissolved in nitric acid, and the uranium was purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating converted the nitrate solution to uranium trioxide (UO_3) powder. This compound was reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal was then remelted with scrap uranium metal to yield a purified uranium ingot.

Operable Unit 2 wastes are wastes from the Sanitary Landfill, the Lime Sludge Ponds, the Active Fly Ash Pile, the Inactive Fly Ash Disposal Area, and the Southfield.

C.4.0 TASK-SPECIFIC HAZARD ASSESSMENT

The following hazard assessment is based on historical information and defined task activities. Laboratory personnel routinely reassess the hazards before beginning work, to ensure that conditions have not changed. All newly identified hazards will be addressed with the H&S Officer to determine the degree of hazard and if any changes to the HSP are needed.

C.4.1 PHYSICAL HAZARDS

The physical hazards involved in the testing procedures are high temperature furnace operation and radiological hazards (U-238 and its daughter products). Table C-1 shows derived air concentrations (DACs) and action limits for the latter.

TABLE C-1

PHYSICAL HAZARDS

Contaminant	DAC[a]	Action Limit .25 x DAC[a]
Thorium-230	3E-12 µCi/mℓ	7.5E-13 µCi/mℓ
Uranium-238	2E-11 µCi/mℓ	5E-12 µCi/mℓ
Uranium-234	2E-11 µCi/mℓ	5E-12 µCi/mℓ

[a] DAC - Derived Air Concentration

A high temperature furnace (up to 550°C) will be used to process Sanitary Landfill samples. The Laboratory Project Supervisor shall review the preliminary characterization results obtained in Appendix B to ensure that samples can be heated without threat of fire or explosion. Samples will not be heated until this review is completed satisfactorily. Workers shall follow proper safe work practices and protective clothing requirements of this HSP while performing operations involving the furnace.

C.4.2 CHEMICAL HAZARDS

The chemicals in Table C-2 will be used as reagents or may be present in the samples and pose potential hazards. Other materials, such as fly ash, lime, and cement/sodium silicate will be present, but pose no significant hazard due to their relatively low toxicity and small quantities.

TABLE C-2

CHEMICALS THAT POSE POTENTIAL HAZARDS

Chemical	Permissible Exposure Limit (PEL[a])		
	TWA[b]	STEL[c]	C[d]
Reagents			
Acetic acid	10mg/m^3	None	
Sodium hydroxide	None		2mg/m^3
Contaminants			
Uranium (soluble compounds)	0.05mg/m^3		
Uranium (insoluble compounds)	0.2mg/m^3	0.6mg/m^3	

[a] PEL - Permissible exposure limit (maximum airborne exposure allowed by the Occupational Health and Safety Administration (OSHA)
[b] TWA - Time-weighted exposure limit (average exposure allowed over an 8-hour shift
[c] STEL - Short-term exposure limit (maximum average exposure during a 15-minute period
[d] Ceiling - Maximum allowable instantaneous exposure

C.4.3 POTENTIAL ROUTES OF EXPOSURE AND HAZARD ASSESSMENT

The identified site wastes are solid in nature and the majority of the reagents to be used are liquids. The potential routes of entry into the body are inhalation, absorption, and ingestion, in their order of importance. Radioisotopes in the samples pose an external and internal exposure hazard. The internal hazard is largely eliminated by the procedures to be utilized. The external hazard will be controlled

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through air monitoring. Direct skin contact with the corrosives may result in destruction of skin tissue and absorption of other contaminants if in solution.

In order to minimize the potential exposure hazards, nearly all of the operations to be carried out during this project will be performed inside a laboratory exhaust hood, which is located inside an environmental containment cubicle. These operations include sample preparation, pouring reagents, and packaging for disposal. The only operations planned to be performed outside the hood are transport of the waste samples to and from the hood and transport of containerized reagents to the hood. All container opening will be done only inside the hood. Reagents have been prepared and packaged at an off-site location to further minimize on-site handling.

The use of the hood greatly minimizes any potential for exposure to the hazards associated with the samples or the reagents. To minimize the potential for radiation exposure, air monitoring will be conducted to quantify the exposure and to assure that the procedures in use are appropriate.

C.5.0 MONITORING

C.5.1 GOALS

Air monitoring for chemical exposure (reagents, etc.) will not be necessary because chemical concentrations in the workers' breathing zone should neither approach nor exceed the concentrations specified by established exposure levels.

Exposures to chemicals should be kept as low as possible, because there are insufficient data to predict the combined effects of most chemical mixtures.

C.5.2 EXTERNAL RADIATION HAZARD MONITORING

A health physics technician will monitor all locations before start of work and will frequently monitor exposures in all areas that exceed the one millirem (mrem)/hour action limit. Measures such as increasing shielding, increasing distance, or reducing exposure time will be taken to minimize exposures. Radiation monitoring instruments include:

- Ludlum Model 177, or equivalent, with a G-M pancake probe;
- Ludlum Model 3, or equivalent, with a ZnS alpha scintillation probe; and
- Eberline Model Alpha-5A alpha air monitor.

C.5.3 ACTION LIMITS

Table C-3 provides types, scheduling, and actions for monitoring.

TABLE C-3

MONITORING TYPES, SCHEDULING, AND ACTIONS

Instrument/Chemical	Interval	Limit	Action
Alpha probe	Pre-job and intermittent	20 cpm[a]	HP Review
Beta/gamma probe	Pre-job and intermittent	500 cpm[a]	HP Review
External radiation	Pre-job	>1 mrem/hour	HP Review
Continuous air monitor (CAM)	Continuous	7.5 E-13 µCi/mℓ (25% Th-230 MPC)	APR Withdraw
Thermoluminescent dosimetry (TLD) badge	Continuous	N/A, no real time results	

[a] Above background

C.6.0 PERSONAL PROTECTIVE EQUIPMENT AND EXPOSURE REDUCTION

C.6.1 PERSONAL PROTECTIVE EQUIPMENT

C.6.1.1 Respiratory Protection

The need for respiratory protection shall be evaluated, prior to the commencement of activities, by a professional industrial hygienist and health physicist.

C.6.1.2 Eye Protection

Personnel using concentrated acids and bases in the performance of testing shall wear face shields with goggles to protect themselves from splashes. Personnel who work at or in the vicinity of the high temperature furnace shall wear tinted safety shields.

C.6.1.3 Protective Clothing

Personnel who work with concentrated acids and bases shall wear rubber aprons, long-sleeved clothing, and chemical-resistant gloves. Those workers at or in the vicinity of the high temperature furnace shall wear heat-resistant gloves and jackets.

C.6.2 EXPOSURE REDUCTION

C.6.2.1 Engineering Controls

The operations shall be performed under a laboratory exhaust hood in an environmental containment cubicle, under negative ventilation. This cubicle is located in the environmental containment cubicle room, which is also under negative ventilation. A slant manometer or magnehelic gauge shall be utilized to measure and indicate the pressure differential created by the air flow.

The laboratory exhaust hoods will be kept free of materials placed where they could block the vents and reduce air flow.

C.6.2.2 Administrative Controls

Access Control to Work Area

Access to contamination work areas shall be regulated and limited to authorized personnel. Warning signs shall be affixed in readily visible locations in or near the work area as required by applicable regulations.

The work area shall be divided into the following three zones:

- Exclusion zone - This zone will include the highest potential concentrations of contaminants. This zone has the highest potential for skin contamination and inhalation exposures. The exclusion zone will be the environmental containment cubicle.

- Contamination reduction zone - This zone includes all areas immediately adjacent to the exclusion zone. Personnel contamination monitoring will take place in this zone.

- Support zone - This area covers all areas outside of the contamination reduction zone. Exposure to harmful chemicals or radioactive materials in this zone is highly unlikely.

C.6.2.3 Safe Work Practices

All personnel shall follow the safe work practices outlined in the chemical hygiene plan for the ETDC.

C.6.2.4 Equipment Inspection

All equipment used in the testing shall be inspected prior to use. Defective equipment will be reported to the Project Manager and repaired or replaced prior to use.

C.7.0 LABORATORY ACCESS AND ENTRY PROCEDURES

Access to the environmental containment cubicles during treatability studies will be limited to personnel who have completed required training and have had required medical exams.

C.7.1 BIOASSAY SAMPLING

A baseline 24-hour urine sample shall be taken before starting treatability activities and a post-work 24-hour urine sample shall be submitted upon completion of activities.

Additional urine samples will be required if air samples indicate an acute exposure of 40 DAC-hours (two percent of the annual limit of intake). This correlates to a gross alpha activity for the most conservative nuclide, Th-230, of 1E-10 µCi/mℓ averaged over a one-hour exposure. No respirator protection factors are built into these action levels.

C.7.2 MEDICAL MONITORING

In accordance with 29CFR1910.120 OSHA requirements, all personnel involved in the treatability study are required to participate in a medical monitoring program which includes:

- A baseline medical examination
- An annual medical examination
- Medical examinations that may be required after potential exposures.

C.7.3 TRAINING REQUIREMENTS

All ETDC personnel involved in the treatability study shall have the following training:

- IT Chemical Hygiene Plan
- ETDC Emergency Contingency Plan
- General Employee Training - Rad Worker Training
- Hazard Communication Training

Documentation of employee training can be obtained from the regional Health and Safety Coordinator.

C.7.4 EXCLUSION ZONE

The exclusion zone is the zone of high potential hazard due to physical, chemical, or radiological dangers. Access to the exclusion zone is restricted to employees who must enter in order to perform their job

functions. The areas inside the environmental containment cubicles are considered to be the exclusion zones.

C.7.5 LABORATORY ENTRY PROCEDURES

The following activities shall be conducted prior to and during the work day, as appropriate:

- Perform respirator check-out and fit-test prior to use
- Locate the nearest eyewash/shower and fire extinguisher prior to initiating activities
- Verify that all instruments are calibrated
- Visually scan the laboratory for signs of contamination.

Note: The H&S Manager and all members of the team have the authority to halt the work if and when imminent or serious safety hazards or conditions exist. Restart of work will be allowed only after the hazard or condition has been abated or reduced to an acceptable level.

C.8.0 LABORATORY EXITING PROCEDURE

C.8.1 CONTAMINATION DETECTION

All personnel are required to follow decontamination procedures themselves and then confirm the effectiveness of the decontamination. The effectiveness shall be determined by frisking with a hand-held radiation monitor.

The monitor must be held within 1/2 inch of the surface and moved at a rate of approximately one inch per second for effective radiation monitoring. If the frisking count exceeds "detectable," additional decontamination is required. This decontamination will be conducted by gently scrubbing with soap and water.

In the event that contamination cannot be removed to below the action levels (100 cpm beta/gamma or detectable alpha radiation above background), the H&S Manager shall be notified.

C.8.2 DECONTAMINATION

Decontamination reduces contaminant concentrations to acceptable levels, but does not generally remove it totally. Contamination shall be avoided, where possible, by making minimum contact with the contaminant.

Personnel decontamination procedures are as follows: remove disposable protective (dry) equipment; gently scrub hands, face, and any other exposed skin that has contacted potentially contaminated wastes with detergent and tepid water.

Equipment decontamination procedures are as follows: Any exposed areas of the equipment surface shall be wiped with a damp paper towel/cloth to remove contamination (dampening with a detergent solution may be necessary for removal of greasy materials).

The effectiveness of decontamination must be confirmed by frisking.

C.9.0 EXPOSURE SYMPTOMS

Acute exposure to solvents and corrosives may produce dizziness and/or irritation. Exposure to low levels of radioactivity do not produce acute exposure symptoms, but may cause delayed effects such as cancer. Since biological effects from radiation exposures are cumulative, exposures are to be kept as low as reasonably achievable (ALARA).

In the event of an accident or emergency release, refer to the Emergency Contingency Plan (ECP) prepared for the ETDC.

C.10.0 OPERATIONALLY DERIVED WASTES

Operationally derived wastes are wastes generated in the performance of various activities. These wastes include, but are not limited to, disposable personal protective equipment, such as Tyvek coveralls, gloves, and booties and disposable decontamination supplies.

Protective clothing will be placed in plastic bags, placed in a B-25 box or metal drum, and returned to the Fernald site.

Operationally derived wastes are the property of the client and are to be shipped back to the Fernald site (currently operated by Westinghouse Environmental Management Company of Ohio) unless otherwise specified in the written contract.

The client will be responsible for proper transport, shipment, or disposal unless otherwise specified in the written contract.

C.11.0 CONTINGENCY PLANS

Contingency plans for injuries, spills, releases, fires, and explosions are given in the ECP for the ETDC. The ECP identifies ETDC emergency coordinators. Agencies that may be requested to provide assistance in an emergency are also listed along with phone numbers. All employees at the ETDC are provided with a copy of the ETDC ECP.

APPENDIX D

TECHNOLOGY DEVELOPMENT LABORATORY STANDARD OPERATING PROCEDURES

International Technology Corporation

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Bulking Factor Measurement

Prepared by: Charley Morgan Date: 2/7/91

Reviewed by: Ed Olpek Date: 2/8/91
Technical Specialist

Patti B. Carswell Date: 2/8/91
Quality Control Coordinator

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Director, Quality and Compliance, ITAS

Approved by: R L Miller Date: 3/27/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

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IT Corporation is a wholly owned Subsidiary of International Technology Corporation

.0 Purpose and Application

1.1 The purpose of this SOP is to determine the volume increase when additives are mixed with homogenized sludge. This procedure proves to be the best test instead of trying to read the volume increase directly from a plastic or glass container because the sludge tends to stick to the sides, therefore giving an erroneous result.

2.0 References

2.1 ITAS-TDL Chemical Hygiene Plan.

3.0 Associated SOPs and Applicable Methods

3.1 None

4.0 Definitions

4.1 Container Volume (A)

The volume of deionized water that the container will hold.

4.2 Volume of Water Plus Sludge (B)

The amount of deionized water it takes to fill container with a known weight of sludge

4.3 Initial Volume (I)

Initial volume of sludge in cm^3.

4.4 Volume of Water with Treated Sludge (C)

Amount of deionized water needed to fill container that contains treated sludge.

4.5 Treated Sludge

Raw sludge that has been mixed with additives.

4.6 Treated Volume (D)

Treated volume amount of sludge.

4.7 Change in Volume (BF)

Difference of initial volume (I) of sludge and treated volume (D) of sludge.

5.0 Procedure

5.1 Summary

5.1.1 A known volume of deionized water is added to a known weight of a sludge sample. A percent volume change is then calculated.

5.2 Interferences

5.2.1 No known interferences.

5.3 Sample Handling, Preservation, and Holding Time

5.3.1 Application of these procedures on hazardous waste samples must consider the known or suspected hazardous compounds present. Project-specific selection of work area, safe working practices, and personal protective equipment shall be made based upon exposure potential to the hazardous components.

5.3.2 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.3.3 There are no holding times applicable to this procedure.

5.3.4 There are no preservation requirements applicable to this procedure.

5.4 Required Equipment

5.4.1 Two 5-oz. S/P Dispo® polypropylene container or equivalent.

5.4.2 Graduated cylinder.

5.5 Reagents/Standards

5.5.1 Deionized water.

5.5.2 Additives.

5.0 Procedure (continued)

5.6 Calibration

5.6.1 Determine the container volume (A). For example, a 5-oz. S/P Dispo® polypropylene container which is graduated from 10 to 140 ml is used. Calibrate the 5-oz container by filling the container with deionized water using a graduate cylinder.

5.7 Analysis/Operation

5.7.1 Add a known weight in grams of raw sludge to a 5-oz container. Tap container with raw sludge to release air bubbles. Add deionized water by a graduate into container until full. Designate the volume of deionized water added as the volume of water plus sludge (B).

5.7.2 In another 5-oz container, add same weight as above of raw sludge plus the percent additives and mix well. Tap container to release air pockets. Fill rest of container using a graduate with deionized water. Designate the volume of deionized water added as volume of water with treated sludge (C).

5.8 Calculations

5.8.1 Initial volume (I) of sludge is equal to (A-B) and units are in cm^3.

$$A - B = I$$

where: A = container volume and
B = volume of water plus sludge.

5.8.2 (A-C) equals treated volume (D).

$$A - C = D$$

where: A = container volume,
C = volume of water with treated sludge, and
D = treated volume.

5.8.3 Calculate the difference of initial volume (I) and treated volume (D). Designate this amount as change in Volume (BF).

$$D - I = BF$$

where: I = initial volume,
D =treated volume, and
BF = change in volume.

5.0 Procedure (continued)

5.8.4 To get percent change in volume, take (BF) divided by initial volume (I) and multiply by 100.

$$\% \text{ Change in Volume} = BF/I \times 100$$

where: BF = change in volume and
I = initial volume.

5.9 Quality Control

5.9.1 None

6.0 Nonconformance and Corrective Action

6.1 Any failure to follow this procedure will be noted on a nonconformance memo. The corrective action will be verified by the Quality Control Coordinator and approved by the appropriate Operations Manager.

7.0 Records Management

7.1 All data will be recorded in standard laboratory notebooks.

STANDARD OPERATING PROCEDURE

ITAS-TECHNOLOGY DEVELOPMENT LABORATORY

TITLE:	SOP NO: TDL1109
UNCONFINED COMPRESSIVE STRENGTH	DATE INITIATED: 7/31/89 REVISION NO: 1 DATE REVISED: 3/28/90 PAGE 1 OF 19

PREPARED BY	APPROVED BY	DATE	QA CONCURRENCE	DATE
John F. McGahan	E. Olson	3/28/90	Janet M. Jones	9-4-90

1.0 Purpose and Application

1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel bleed water during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils.

2.0 References

2.1 Annual Book of ASTM Standards. 1988. "Soil and Rock; Building Stones; Geotextiles. Vol. 4.08.

3.0 Associated SOPs and Applicable Methods

3.1 ASTM D-422.

3.2 ASTM D-854.

3.3 ASTM D-2216.

3.4 ASTM D-2850.

3.0 Associated SOPs and Applicable Methods (continued)

3.5 ASTM D-4220.

3.6 ASTM D-4318.

4.0 Definitions

4.1 Unconfined compressive strength - the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test.

4.2 Shear strength - for unconfined compressive strength test specimens, the shear strength is calculated to be one-half of the compressive stress at failure.

4.3 Bleed water - water expelled from the soil due to deformation or compaction.

5.0 Procedure

5.1 ASTM Standard Method D-2166.

6.0 Nonconformance and Corrective Action

6.1 If this procedure cannot be followed for any reason, a nonconformance memo will be filed with the Quality Control Coordinator. Corrective action will be approved by the Operations or Project Manager.

7.0 Records Management

7.1 Data is to be recorded in a standard laboratory notebook with the project it pertains to clearly labeled on the notebook page.

Designation: D 2166 – 85

Standard Test Method for UNCONFINED COMPRESSIVE STRENGTH OF COHESIVE SOIL[1]

This standard is issued under the fixed designation D 2166; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition, using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel bleed water (water expelled from the soil due to deformation or compaction) during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved materials, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compression strength values.

NOTE — The determination of the unconsolidated, undrained strength of cohesive soils with lateral confinement is covered by Test Method D 2850.

1.4 This test method is not a substitute for Test Method D 2850.

1.5 The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Applicable Documents

2.1 *ASTM Standards:*

D 422 Method for Particle-Size Analysis of Soils[2]

D 653 Terms and Symbols Relating to Soil and Rock[2]

D 854 Test Method for Specific Gravity of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 2850 Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

3. Terminology

3.1 Refer to Terms and Symbols D 653 for standard definitions of terms.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Structural Properties of Soils.

Current edition approved July 26, 1985. Published September 1985. Originally published as D 2166 – 63T. Last previous edition D 2166 – 66 (1979)ε[1].

[2] *Annual Book of ASTM Standards*, Vol 04.08.

3.2 *Descriptions of Terms Specific to this Standard:*

3.2.1 *unconfined compressive strength (q_u)*—the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test method, unconfined compressive strength is taken as the maximum load attained per unit area or the load per unit area at 15 % axial strain, whichever is secured first during the performance of a test.

3.2.2 *shear strength (s_u)*—for unconfined compressive strength test specimens, the shear strength is calculated to be ½ of the compressive stress at failure, as defined in 3.2.1.

4. Significance and Use

4.1 The primary purpose of the unconfined compression test is to quickly obtain the approximate compressive strength of soils that possess sufficient cohesion to permit testing in the unconfined state.

4.2 Samples of soils having slickensided or fissured structure, samples of some types of loess, very soft clays, dry and crumbly soils and varved materials, or samples containing significant portions of silt or sand, or both (all of which usually exhibit cohesive properties), frequently display higher shear strengths when tested in accordance with Test Method D 2850. Also, unsaturated soils will usually exhibit different shear strengths when tested in accordance with Test Method D 2850.

4.3 If both an undisturbed and a remolded test are performed on the same sample, the sensitivity of the material can be determined. This method of determining sensitivity is suitable only for soils that can retain a stable specimen shape in the remolded state.

NOTE 2—For soils that will not retain a stable shape, a vane shear test or Test Method D 2850 can be used to determine sensitivity.

5. Apparatus

5.1 *Compression Device*—The compression device may be a platform weighing scale equipped with a screw-jack-activated load yoke, a hydraulic loading device, or any other compression device with sufficient capacity and control to provide the rate of loading prescribed in 7.1. For soil with an unconfined compressive strength of less than 100 kPa (1.0 ton/ft²) the compression device shall be capable of measuring the compressive stress to within 1 kPa (0.01 ton/ft²). For soil with an unconfined compressive strength of 100 kPa (1.0 ton/ft²) or greater, the compression device shall be capable of measuring the compressive stress to the nearest 5 kPa (0.05 ton/ft²).

5.2 *Sample Extruder*, capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube, at a uniform rate, and with negligible disturbance of the sample. Conditions at the time of sample removal may dictate the direction of removal, but the principal concern is to keep the degree of disturbance negligible.

5.3 *Deformation Indicator*—The deformation indicator shall be a dial indicator graduated to 0.03 mm (0.001 in.) or better and having a travel range of at least 20 % of the length of the test specimen, or some other measuring device, such as an electronic deformation measuring device, meeting these requirements.

5.4 *Dial Comparator*, or other suitable device, for measuring the physical dimensions of the specimen to within 0.1 % of the measured dimension.

NOTE 3—Vernier calipers are not recommended for soft specimens, which will deform as the calipers are set on the specimen.

5.5 *Timer*—A timing device indicating the elapsed testing time to the nearest second shall be used for establishing the rate of strain application prescribed in 7.1.

5.6 *Balance*—The balance used to weigh specimens shall determine the mass of the specimen to within 0.1 % of its total mass.

5.7 *Equipment*, as specified in Method D 2216.

5.8 *Miscellaneous Apparatus*, including specimen trimming and carving tools, remolding apparatus, water content cans, and data sheets, as required.

6. Preparation of Test Specimens

6.1 *Specimen Size*—Specimens shall have a minimum diameter of 30 mm (1.3 in.) and the largest particle contained within the test specimen shall be smaller than one tenth of the specimen diameter. For specimens having a diameter of 72 mm (2.8 in.) or larger, the largest particle size shall be smaller than one sixth of the specimen diameter. If, after completion of a test on

an undisturbed specimen, it is found, based on visual observation, that larger particles than permitted are present, indicate this information in the remarks section of the report of test data (Note 4). The height-to-diameter ratio shall be between 2 and 2.5. Determine the average height and diameter of the test specimen using the apparatus specified in 5.4. Take a minimum of three height measurements (120° apart), and at least three diameter measurements at the quarter points of the height.

NOTE 4—If large soil particles are found in the sample after testing, a particle-size analysis performed in accordance with Method D 422 may be performed to confirm the visual observation and the results provided with the test report.

6.2 *Undisturbed Specimens*—Prepare undisturbed specimens from large undisturbed samples or from samples secured in accordance with Practice D 1587 and preserved and transported in accordance with the practices for Group C samples in Practices D 4220. Tube specimens may be tested without trimming except for the squaring of ends, if conditions of the sample justify this procedure. Handle specimens carefully to prevent disturbance, changes in cross section, or loss of water content. If compression or any other noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut it off in small sections to facilitate removal of the specimen without disturbance. Prepare carved specimens without disturbance, and whenever possible, in a humidity-controlled room. Make every effort to prevent any change in water content of the soil. Specimens shall be of uniform circular cross section with ends perpendicular to the longitudinal axis of the specimen. When carving or trimming, remove any small pebbles or shells encountered. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. When pebbles or crumbling result in excessive irregularity at the ends, cap the specimen with a minimum thickness of plaster of paris, hydrostone, or similar material. When sample condition permits, a vertical lathe that will accommodate the total sample may be used as an aid in carving the specimen to the required diameter. Where prevention of the development of appreciable capillary forces is deemed important, seal the specimen with a rubber membrane, thin plastic coatings, or with a coating of grease or sprayed plastic immediately after preparation and during the entire testing cycle. Determine the mass and dimensions of the test specimen. If the specimen is to be capped, its mass and dimensions should be determined before capping. If the entire test specimen is not to be used for determination of water content, secure a representative sample of cuttings for this purpose, placing them immediately in a covered container. The water content determination shall be performed in accordance with Method D 2216.

6.3 *Remolded Specimens*—Specimens may be prepared either from a failed undisturbed specimen or from a disturbed sample, providing it is representative of the failed undisturbed specimen. In the case of failed undisturbed specimens, wrap the material in a thin rubber membrane and work the material thoroughly with the fingers to assure complete remolding. Avoid entrapping air in the specimen. Exercise care to obtain a uniform density, to remold to the same void ratio as the undisturbed specimen, and to preserve the natural water content of the soil. Form the disturbed material into a mold of circular cross section having dimensions meeting the requirements of 6.1. After removal from the mold, determine the mass and dimensions of the test specimens.

6.4 *Compacted Specimens*—Specimens shall be prepared to the predetermined water content and density prescribed by the individual assigning the test (Note 5). After a specimen is formed, trim the ends perpendicular to the longitudinal axis, remove from the mold, and determine the mass and dimensions of the test specimen.

NOTE 5—Experience indicates that it is difficult to compact, handle, and obtain valid results with specimens that have a degree of saturation that is greater than 90 %.

7. Procedure

7.1 Place the specimen in the loading device so that it is centered on the bottom platen. Adjust the loading device carefully so that the upper platen just makes contact with the specimen. Zero the deformation indicator. Apply the load so as to produce an axial strain at a rate of ½ to 2 %/min. Record load, deformation, and time values at sufficient intervals to define the shape of the stress-strain curve (usually 10 to 15 points are sufficient). The rate of strain should be chosen so that the time to failure does not exceed about

15 min (Note 6). Continue loading until the load values decrease with increasing strain, or until 15 % strain is reached. The rate of strain used for testing sealed specimens may be decreased if deemed desirable for better test results. Indicate the rate of strain in the report of the test data, as required in 9.1.7. Determine the water content of the test specimen using the entire specimen, unless representative cuttings are obtained for this purpose, as in the case of undisturbed specimens. Indicate on the test report whether the water content sample was obtained before or after the shear test, as required in 9.1.2.

NOTE 6—Softer materials that will exhibit larger deformation at failure should be tested at a higher rate of strain. Conversely, stiff or brittle materials that will exhibit small deformations at failure should be tested at a lower rate of strain.

7.2 Make a sketch, or take a photo, of the test specimen at failure showing the slope angle of the failure surface if the angle is measurable.

7.3 A copy of a sample data sheet is included in Appendix X1. Any data sheet can be used, provided the form contains all the required data.

8. Calculations

8.1 Calculate the axial strain, ϵ_1, to the nearest 0.1 %, for a given applied load, as follows:

$$\epsilon_1 = \Delta L / L_0$$

where:

ΔL = length change of specimen as read from deformation indicator, mm (in.), and

L_0 = initial length of test specimen, mm (in.).

8.2 Calculate the average cross-sectional area, A, for a given applied load, as follows:

$$A = A_0/(1 - \epsilon_1)$$

where:

A_0 = initial average cross-sectional area of the specimen, mm² (in.²), and

ϵ_1 = axial strain for the given load, %.

8.3 Calculate the compressive stress, σ_c, to three significant figures, or nearest 1 kPa (0.01 ton/ft²), for a given applied load, as follows:

$$\sigma_c = (P/A)$$

where:

P = given applied load, kPa (ton/ft²),

A = corresponding average cross-sectional area mm² (in.²).

8.4 *Graph*—If desired, a graph showing the relationship between compressive stress (ordinate) and axial strain (abscissa) may be plotted. Select the maximum value of compressive stress, or the compressive stress at 15 % axial strain, whichever is secured first, and report as the unconfined compressive strength, q_u. Whenever it is considered necessary for proper interpretation, include the graph of the stress-strain data as part of the data reported.

8.5 If the unconfined compressive strength is determined, the sensitivity, S_T, is calculated as follows:

$$S_T = \frac{q_u \text{ (undisturbed specimen)}}{q_u \text{ (remolded specimen)}}$$

9. Report

9.1 The report should include the following:

9.1.1 Identification and visual description of the specimen, including soil classification, symbol, and whether the specimen is undisturbed, remolded, compacted, etc. Also include specimen identifying information, such as project, location, boring number, sample number, depth, etc. Visual descriptions shall be made in accordance with Practice D 2488.

9.1.2 Initial dry density and water content (specify if the water content specimen was obtained before or after shear, and whether from cuttings or the entire specimen).

9.1.3 Degree of saturation (Note 7), if computed.

NOTE 7—The specific gravity determined in accordance with Test Method D 854 is required for calculation of the degree of saturation.

9.1.4 Unconfined compressive strength and shear strength.

9.1.5 Average height and diameter of specimen.

9.1.6 Height-to-diameter ratio.

9.1.7 Average rate of strain to failure, %.

9.1.8 Strain at failure, %.

9.1.9 Liquid and plastic limits, if determined, in accordance with Test Method D 4318.

9.1.10 Failure sketch or photo.

9.1.11 Stress-strain graph, if prepared.

9.1.12 Sensitivity, if determined.

9.1.13 Particle size analysis, if determined, in accordance with Method D 422, and

9.1.14 *Remarks*—Note any unusual conditions or other data that would be considered necessary to properly interpret the results obtained, for example, slickensides, stratification.

shells, pebbles, roots, or brittleness, the type of failure (that is, bulge, diagonal shear, etc.).

10. Precision and Bias

10.1 No method presently exists to evaluate the precision of a group of unconfined compression tests on undisturbed specimens due to specimen variability. Undisturbed soil specimens from apparently homogeneous soil deposits at the same location often exhibit significantly different strength and stress-strain properties.

10.2 A suitable test material and method of specimen preparation have not been developed for the determination of laboratory variances due to the difficulty in producing identical cohesive soil specimens. No estimates of precision for this test method are available.

APPENDIX

(Nonmandatory Information)

X1. Example Data Sheet

UNCONFINED COMPRESSION TEST—UI

Name _____ Date _____ Job No. _____

Location _____

Boring No. _____ Sample No. _____ Depth/Elev. _____

Description of Sample _____

_____

Proving Ring No. _____ Apparatus No. _____

Water Content Determination

Tare No. _____

Wt. Specimen Wet + Tare _____

Wt. Specimen Dry + Tare _____

Wt. Water _____

Wt. Tare _____

Wt. Specimen Wet _____

Wt. Specimen Dry _____

Water Content in % Dry Wt.

at 105°C _____

Wet Density _____

Dry Density _____

Unconfined Compressive Strength

Initial Diameter D_o _____

Initial Area A_o _____

Initial Height L_o _____

Initial Volume V_o _____

Specific Gravity _____

$$\text{Stress} = \frac{\text{Load}}{\text{Corr. Area}}$$

Data sheet continued

ASTM D 2166

Test Data

Unit Strain $\frac{\Delta L}{L_o}$ $\frac{L}{D}$ = _____ Corr. Area = $\frac{A_o}{1 - \text{Unit Strain}}$

Elapsed Time-min	Load Dial	Axial Load	Strain Dial	Total Strain	Unit Strain	Corrected Area	Stress	

Type of Sample _____

Attach a photo or sketch of the specimen after failure to this form

Strain Rate _____ %/Min

Remarks _____

APPENDIX XI:

UNCONFINED COMPRESSION TEST

1. INTRODUCTION. The unconfined compression test is used to measure the unconfined compressive strength of a cohesive soil. The unconfined compression test is applicable only to coherent materials such as saturated clays or cemented soils that retain intrinsic strength after removal of confining pressure; it is not a substitute for the Q test. Dry or crumbly soils, fissured or varved materials, silts, and sands cannot be tested meaningfully in unconfined compression. In this test, a laterally unsupported cylindrical specimen is subjected to a gradually increased axial compression load until failure occurs. The unconfined compression test is a form of triaxial test in which the major principal stress is equal to the applied axial stress, and the intermediate and minor principal stresses are equal to zero. The unconfined compressive strength, q_u, is defined as the maximum unit axial compressive stress at failure or at 15 percent strain, whichever occurs first. The undrained shear strength, s_u, is assumed to be equal to one-half the unconfined compressive strength. The axial load may be applied to the specimen either by the controlled strain procedure, in which the stress is applied to produce a predetermined rate of strain, or by the controlled stress procedure, in which the stress is applied in predetermined increments of load.

2. APPARATUS. The apparatus consists of the following:

a. Equipment for Preparing Specimen. A trimming frame as described in paragraph 3e of Appendix X, TRIAXIAL COMPRESSION TESTS, or a trimming cylinder with beveled cutting edges may be used for trimming specimens. The equipment should include wire saws and knives of various sizes and types for use with the trimming frame. A motorized soil lathe may be used advantageously under certain circumstances. A miter box or cradle is required to trim the specimen to a fixed length and to ensure that the ends of the specimen are parallel with each other and perpendicular to the vertical axis of the specimen.

b. Loading Device. A number of commercially available controlled-strain or controlled-stress types of loading devices are suitable for applying the axial loads in the unconfined compression test. In 117

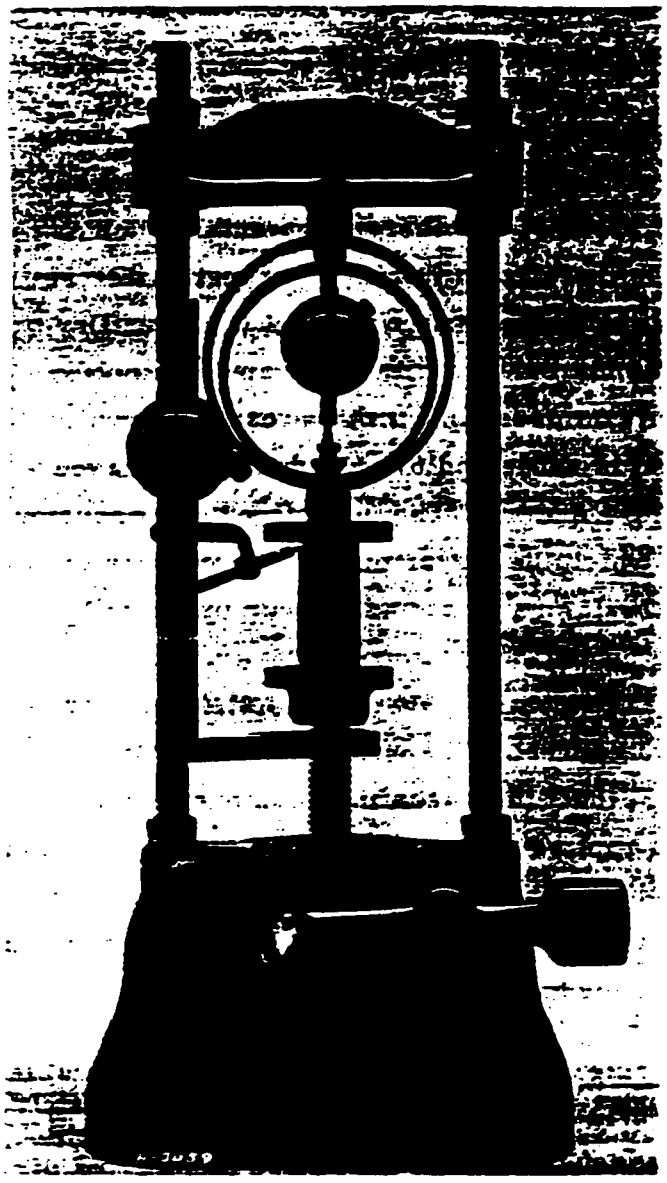

Figure 1. Typical unconfined compression test apparatus

general, controlled-strain type loading devices are preferable, and the procedures described herein are based on the use of this type of equipment. If available, an automatic stress-strain recorder may be used to measure and record applied axial loads and displacements. A typical loading device is shown in Figure 1. Any equipment used should be calibrated so that the loads actually applied to the soil specimen can be determined. The required sensitivity of stress-measuring equipment for both controlled-stress and controlled-strain testing will vary with the strength characteristics of the soil. For relatively weak soils (compressive strengths less than 1.0 ton per sq ft), the unit load should be measurable to within 0.01 ton per sq ft. For soils with compressive strengths of 1.0 ton per sq ft or greater, the loads should be measurable to the nearest 0.05 ton per sq ft.

c. Measuring equipment, such as dial indicators and calipers, suitable for measuring the dimensions and axial deformation of a specimen

to the nearest 0.001 in.

d. Timing device. either a watch or clock with second hand.

e. Balances. sensitive to 0.1 g.

f. Other. Apparatus necessary to determine water content and specific gravity (see Appendixes I, WATER CONTENT - GENERAL, and IV, SPECIFIC GRAVITY).

3. PREPARATION OF SPECIMENS. a. Specimen Size. Unconfined compression specimens shall have a minimum diameter of 1.0 in. (preferably 1.4 in.), and the largest particle in any test specimen will be no greater than one-sixth the specimen diameter. The height-to-diameter ratio shall be not less than 2.1. Commonly used diameters of unconfined compression specimens are 1.4 and 2.8 in. Specimens of 1.4-in. diameter are generally used for testing cohesive soils which contain a negligible amount of gravel.

b. Undisturbed Specimens. Generally, undisturbed specimens are prepared from undisturbed tube or chunk samples of a larger size than the test specimen. Core or thin-wall tube samples of relatively small diameter may be tested without further trimming except for squaring the ends, if the condition of the soil requires this procedure. Specimens must be handled carefully to prevent remolding, changes in cross section, or loss of moisture. To minimize disturbance caused by skin friction between samples and metal sampling tubes, the tubes should be cut into short lengths before ejecting the samples. Sample ejection should be accomplished with a smooth continuous, and fairly rapid motion in the same direction that the sample entered the tube. All specimens shall be prepared in a humid room to prevent evaporation of moisture. The specimen shall be prepared as follows:

(1) From the undisturbed sample cut a section somewhat larger in length and diameter than the desired specimen size.

It is generally desirable to prepare duplicate specimens for unconfined compression testing, and selection of material for testing should be made with this in mind.

(2) Carefully trim the specimen to the required diameter using a trimming frame and various trimming tools (see Fig. 7, Appendix X, TRIAXIAL COMPRESSION TESTS). Remove any small shells or pebbles encountered during the trimming operations. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. Cut the specimen to the required length, using a miter box (see Fig. 8, Appendix X, TRIAXIAL COMPRESSION TESTS). Where the presence of pebbles or crumbling results in excessive irregularity at the ends, cap the specimens with a minimum thickness of plaster of Paris, hydrostone, or other support material. Care must be taken to insure that the ends of the specimen are parallel with each other and perpendicular to the vertical axis of the specimen.

(3) From the soil trimmings obtain 200 g of material for specific gravity and water content determinations (see Appendixes I, WATER CONTENT - GENERAL, and IV, SPECIFIC GRAVITY).

(4) Weigh the specimen to an accuracy of ±0.01 g for 1.4-in.-diameter specimens and ±0.1 g for 2.8-in.-diameter specimens. If specimens are to be capped, they should be weighed before capping.

(5) Measure the height of the specimen with calipers or a scale and the diameter with calipers or circumference measuring devices. If the specimen is cut to a fixed length in a miter box, the length of the miter box can be taken as the height of specimen for routine tests, and additional height measurements are not usually necessary. It is always advisable to measure the diameter of the specimen after trimming, even though specimens are cut to a nominal diameter in a trimming frame. Make all measurements to the nearest ±0.01 in. Determine the average initial diameter, D_o, of the specimen using the diameters measured at the top, D_t, center, D_c, and bottom, D_b, of the specimen, as follows:

$$D_o = \frac{D_t + 2D_c + D_b}{4}$$

(6) If the specimen is not tested immediately after preparation, precautions must be taken to prevent drying and consequent development of capillary stresses. When drying before or during the test is anticipated, the specimen may be covered with a thin coating of grease such as petrolatum. This coating cannot be used if the specimen is to be used in a subsequent remolded test.

c. Remolded Specimens. Remolded specimens usually are prepared in conjunction with tests made on undisturbed specimens after the latter has been tested to failure. The remolded specimens are tested to determine the effects of remolding on the shear strength of the soil. The remolded specimen should have the same water content as the undisturbed specimen in order to permit a comparison of the results of the tests on the two specimens. The remolded specimen shall be prepared as follows:

(1) Place the failed undisturbed specimen in a rubber membrane and knead it thoroughly with the fingers to assure complete remolding of the specimen. Take reasonable care to avoid entrapping air in the specimen and to obtain a uniform density.

(2) Remove the soil from the membrane and compact it in a cylindrical mold with inside dimensions identical with those of the undisturbed specimen. The compaction effort is not critical since the water contents of soils subjected to remolded tests are always considerably wetter than optimum. Care must be taken, however, to insure uniform density throughout the specimen. A thin coat of petrolatum on the inside of the molding cylinder will assist in the removal of the specimen after compaction.

(3) Carefully remove the specimen from the mold, preferably by means of a close fitting piston, and plane off the top of the specimen. The specimen is then ready for testing.

(4) Follow the steps outlined in paragraphs 3b(4) and 3b(5).

4. PROCEDURE. The procedure shall consist of the following steps:

a. Record all identifying information for the sample such as project, boring number, visual classification, and other pertinent data on the data sheet (see Plate XI-1 which is a suggested form). The data sheet is also used for recording test observations described below.

b. Place the specimen in the loading device so that it is centered on the bottom platen; then adjust the loading device carefully so that the loading ram or upper platen barely is in contact with the specimen. If a proving ring is used for determining the axial load, contact of the platen and specimen is indicated by a slight deflection of the proving ring dial. Attach a dial indicator, sensitive to 0.001 in., to the loading ram to measure vertical deformation of the specimen. Record the initial reading of the dial indicator on the data sheet (Plate XI-1). Test the specimen at an axial strain rate of about 1 percent per minute. For very stiff or brittle materials which exhibit small deformations at failure, it may be desirable to test the specimen at a slower rate of strain. Observe and record the resulting load corresponding to increments of 0.3 percent strain for the first 3 percent of strain and in increments of 1 or 2 percent of strain thereafter. Stop the test when the axial load remains constant or when 20 percent axial strain has been produced.

c. Record the duration of the test, in minutes, to peak strength (time to failure), type of failure (shear or bulge), and a sketch of specimen after failure on the data sheet (Plate XI-2).

d. After the test, place the entire specimen or a representative portion thereof in a container of known weight and determine the water content of the specimen in accordance with Appendix I, WATER CONTENT - GENERAL.

5. COMPUTATIONS. The computations consist of the following steps:

a. From the observed data, compute and record on the data sheet (Plate XI-1) the water content, volume of solids, void ratio, degree of

saturation, and dry density, using the formulas presented in Appendix II, UNIT WEIGHTS, VOID RATIO, POROSITY, AND DEGREE OF SATURATION.

b. Compute and record on the data sheet the axial strain, the corrected area, and the compressive stress, at each increment of strain by using the following formulas:

$$\text{Axial strain, } \varepsilon = \frac{\Delta H}{H_o}$$

$$\text{Corrected area of specimen, } A_{corr}, \text{ sq cm} = \frac{A_o}{1 - \varepsilon}$$

$$\text{Compressive stress, tons per sq ft} = \frac{P}{A_{corr}} \times 0.465$$

where

ΔH = change in height of specimen during test, cm

H_o = initial height of specimen, cm

A_o = initial area of specimen, sq cm

P = applied axial load, lb

6. PRESENTATION OF RESULTS. The results of the unconfined compression test shall be recorded on the report form shown as Plate XI-2. Pertinent information regarding the condition of the specimen, method of preparing the specimen, or any unusual features of each specimen (such as slickensides, stratification, shells, pebbles, roots, or brittleness) should be shown under "Remarks." The applied compressive stress shall be plotted versus the axial strain in Plate XI-2. The unconfined compressive strength, q_u, of the specimen shall be taken as the maximum or peak compressive stress. For tests continued to 20 percent strain without reduction of axial load occurring, the unconfined compressive strength as a rule shall be taken as the compressive stress at 15 percent strain.

Where the unconfined compressive strength of a specimen is also obtained after remolding, the sensitivity ratio, S_t, shall also be calculated and reported. The sensitivity ratio is defined as follows:

$$S_t = \frac{q_u \text{ (undisturbed)}}{q_u \text{ (remolded)}}.$$

7. POSSIBLE ERRORS. Following are possible errors that would cause inaccurate determinations of unconfined compressive strength:

a. Test not appropriate to type of soil.

b. Specimen disturbed while trimming.

c. Loss of initial water content. A small change in water content can cause a larger change in the strength of a clay, so it is essential that every care be taken to protect the specimen against evaporation while trimming and measuring, during the test, and when remolding a specimen to determine the sensitivity.

d. Rate of strain or rate of loading too fast.

8. USE OF OTHER TYPES OF EQUIPMENT FOR UNDRAINED SHEAR STRENGTH DETERMINATIONS. Various other types of laboratory equipment, such as cone penetrometers and vane shear apparatus, may be used advantageously in the laboratory as a supplement to the basic unconfined compression test equipment for determining the undrained shear strength of cohesive soils. The use of these testing devices generally results in savings in cost and time. However, the devices should be used with caution until sufficient data and procedural details are established to assure their successful application. Use of such testing apparatus, as a rule,

should be preceded by careful correlations with the results of tests with the basic unconfined compression test equipment on the same type of soil, and correlations developed for a given type of soil should not be used indiscriminately for all soils.

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UNCONFINED COMPRESSION TEST

Date _____

Project _____

Boring No. _____ Sample No. _____

Specimen No.			Classification					
Tare No.				Height	H_o	in.	H_o	cm
Weight, g: Tare plus wet specimen				Average diameter	D_o	in.	D_o	cm
Tare plus dry specimen				Initial area	A_o	sq in.	A_o	sq cm
Water	W_w			Volume in cc = $A_o H_o$			V_o	
Tare				Volume of solids in cc = $W_s \div G_s$			V_s	
Wet specimen	W			Void ratio = $(V_o - V_s) \div V_s$			e_o	
Dry specimen	W_s			Saturation in % = $G_s w_o \div e_o$			S_o	%
Water content	w_o		%	Dry dens., lb/cu ft = 62.4 $(W_s \div V_o)$			γ_d	
Specific gravity of solids	G_s			Note: If only a portion of the specimen is used for the water content determination, $W_s = W \div \left(1 + \frac{w_o}{100}\right)$				

Elapsed Time min	Dial Reading 10^{-} in.	Cumulative Change, ΔH 10^{-} in.	Proving Ring Dial Reading 10^{-} in.	Axial Load, P lb	Axial Strain $\epsilon = \Delta H/H_o$	$1 - \epsilon$	$A_{corr} = A_o/(1-\epsilon)$ sq cm	Compr Stress tons/sq ft $0.465(P/A_{corr})$

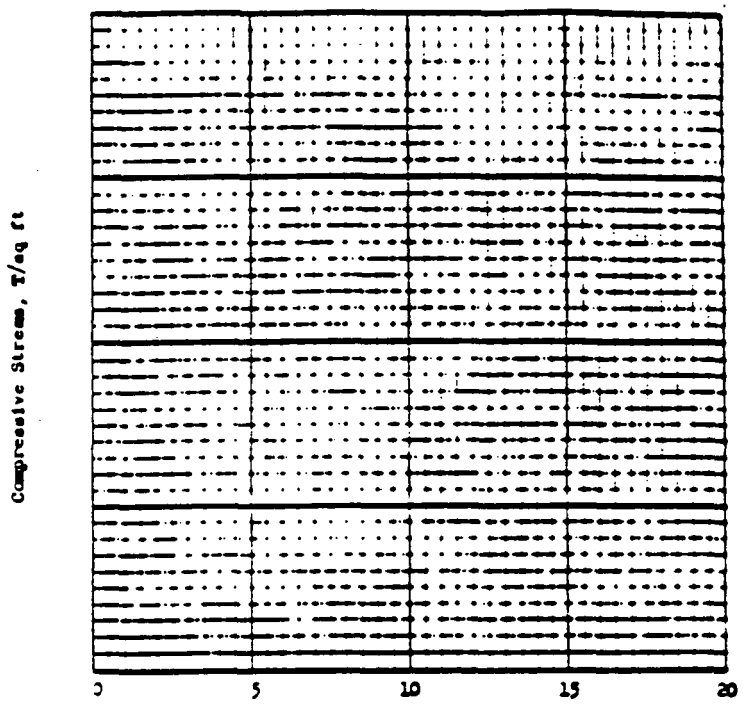
Remarks _____

_____ Type Failure _____

Technician _____ Computed by _____ Checked by _____

PLATE XI-1 ENG FORM 1 JUN 65 3857

Failure Sketches



☐ Controlled stress
☐ Controlled strain

Test No.					
Type of specimen					
Initial: Water content	w_o	%	%	%	%
Initial: Void ratio	e_o				
Initial: Saturation	S_o	%	%	%	%
Initial: Dry density, lb/cu ft	γ_d				
Time to failure, min	t_f				
Unconfined compressive strength, T/sq ft	q_u				
Undrained shear strength, T/sq ft	s_u				
Sensitivity ratio	S_t				
Initial specimen diameter, in.	D_o				
Initial specimen height, in.	H_o				
Classification					
LL	PL	PI	G_s		

Remarks

Project	
Area	
Boring No.	Sample No.
Depth ft	Date

UNCONFINED COMPRESSION TEST REPORT

ENG FORM 1 JUN 68 3659

PLATE XI-2

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Laboratory Notebook Recording Procedures

Prepared by: Patti B. Carswell Date: 2/7/91

Reviewed by: Bruce F. Wagner Date: 2/7/91
Technical Specialist

Patti B. Carswell Date: 2/7/91
Quality Control Coordinator

Janet M. Jones Date: 3-26-91
Director, Quality and Compliance, ITAS

Approved by: R. Miller Date: 3/27/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: NOTEBOOK

Revision #	0					
Date	1-21-91					

1.0 Purpose and Application

1.1 The purpose of this method is to describe the required methods of data entry in Technology Development Laboratory notebooks.

1.2 This procedure applies to laboratory notebooks used for project-specific and non-project-specific documentation.

1.3 The purpose of each entry in your notebook is to provide a complete record of your work, one that would enable a co-worker to repeat, if necessary, exactly what you did and produce the same results, without having to ask any questions.

2.0 References

2.1 Writing the Laboratory Notebook, Howard M. Kanare, 1985.

3.0 Associated SOPs and Applicable Methods

3.1 ITAS SOP No. TDL1503, "Analytical Logbook Recording Procedures."

4.0 Definitions

4.1 None

5.0 Procedure

5.1 Safety

5.1.1 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.1.2 All laboratory notebooks must be kept free of chemical contamination while being used on benchtops, in field settings, etc.

5.2 Summary

5.2.1 All laboratory notebooks are the property of the International Technology Corporation (IT) Technology Development Laboratory (TDL). It is assigned to you so that you may keep a complete, careful, chronological record of your work. The work which you do and the data which you enter in the notebook are confidential; they must not be disclosed to unauthorized persons. The notebook's security and maintenance are your responsibility. In case of damage, loss, or disappearance, report the

5.0 Procedure (continued)

facts to your supervisor at once. When the notebook is filled or upon termination of your employment, it must be returned to the laboratory quality/operation files.

5.3 Procedure

5.3.1 All data is to be recorded directly into the notebook. Recording of original data on loose pieces of paper for later transcription into the logbook is to be avoided. Should loose paper be necessary for proper conduct of an experiment:

5.3.1.1 Write on the logbook page itself identification of what is affixed to that page.

5.3.1.2 Firmly affix the loose paper with clear tape

5.3.1.3 Initial and date over the edge of the tape.

5.3.2 All entries must be made in black ink. Red ink is reserved for Quality Control (QC) checking purposes only. Erasures, blacking out, or use of correction fluid is not permitted. If a mistake is made, draw a single line through the erroneous material and make a corrected entry, initial, and date the correction.

5.3.3 It is necessary to fill each page and keep the sequence of entries in chronological order. Several pages may be reserved for a particular experiment. However, if the continuity of pages for a particular experiment is broken for lack of reserved space, notations will be made on both sides of the break. The unused balance of a page will be cancelled by a diagonal line. Spaces intentionally left blank in tables or logs will contain horizontal lines.

5.3.4 Stock or standard solutions must reference:

5.3.4.1 Source
5.3.4.2 Lot number
5.3.4.3 Date received
5.3.4.4 Notebook and page numbers whenever available.

5.3.5 When reference is made to samples, the TDL sample number must be used. Additional sample identification may be offered, but not to the exclusion of the TDL sample number.

5.3.6 A co-worker performs a QC check on your calculations by recalculating 20 percent and verifying the formula used. Have him make a check in red ink beside each answer which was recalculated and sign and date

5.0 Procedure (continued)

calculations that lead to the generation of a result which is reported to the client either verbally or in writing. Any values which have not had a 20 percent QC check (one of every five calculations has been checked) are considered "preliminary" and will be marked as such on any material leaving the TDL lab. If an error is found during the 20 percent check, then a 100 percent QC check will be performed.

5.3.7 If one of your co-workers has witnessed an experiment you have conducted, to an extent that enables him to state of his own knowledge what you did and what results you secured, have him sign and date the notebook page(s) as "Witnessed and understood by." If the experiment seems to you to be of sufficient importance (i.e., is potentially patentable), arrange to have it witnessed for content and date of entry.

5.4 Project Documentation Requirements

5.4.1 Every page of the notebook will contain project name, project number, date, and initials of persons entering data. Each project will then be described by the following entries:

5.4.1.1 Objective - briefly describe the planned experiment and the expected or desired result.

5.4.1.2 Plan - give an overview of what you intend to do.

5.4.1.3 Calibrations and Standards - list frequency of calibration, acceptance limits, and concentrations.

5.4.1.4 Analytical Methods - state SOP, standard reference or give a brief description.

5.4.1.5 Experimental Set-ups - sketch and describe the set-up.

5.4.1.6 Data and Observations - provide tables including units and space for observations within or below.

5.4.1.7 Results - include formula and calculations which are necessary to produce results from raw data.

5.4.1.8 Conclusion - how objective was met and any interpretation of results.

5.0 Nonconformance and Corrective Action

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6.1 A nonconformance is a deficiency in procedure sufficient to render the quality of an item unacceptable or indeterminate or any event which is beyond the limits documented and established for laboratory operation. A nonconformance may include data recording errors, transcription errors, and failure to document. A nonconformance memo associated with this procedure will be filed with the QC Coordinator.

7.0 Records Management

7.1 TDL Notebooks are the property of IT Corporation.

7.2 Document control of TDL Notebooks is handled by the QC Coordinator (QCC). The QCC will issue all notebooks. All completed notebooks will be returned to the QCC.

7.3 All returned Laboratory Notebooks are filed in TDL Central Files.

International Technology Corporation

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Analytical Logbook Recording Procedures

Prepared by: Patti B. Carswell Date: 2/7/91

Reviewed by: Bruce F. Wagner Date: 2/7/91
Technical Specialist

Patti B Carswell Date: 2/7/91
Quality Control Coordinator

Janet M. Jones Date: 3-26-91
Director, Quality and Compliance, ITAS

Approved by: R S Miller Date: 6/7/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: Logbook, Notebook

Revision #	0					
Date	1-21-91					133

Technology Development Laboratory
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IT Corporation is a wholly owned Subsidiary of International Technology Corporation

1.0 Purpose and Application

1.1 The purpose of this method is to describe the required methods of data entry in Technology Development Analytical Logbooks.

1.2 This procedure applies to analytical logbooks such as instrument injection logbooks, maintenance logbooks, and balance logs.

2.0 References

2.1 Writing the Laboratory Notebook, Howard M. Kanare, 1985.

3.0 Associated SOPs and Applicable Methods

3.1 ITAS SOP No. TDL1504, "Laboratory Notebook Recording Procedures."

4.0 Definitions

4.1 None

5.0 Procedure

5.1 Safety

5.1.1 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.1.2 All analytical logbooks must be kept free of chemical contamination while being used on benchtops, in field settings, etc.

5.2 Summary

5.2.1 All logbooks are the property of the International Technology Corporation (IT) Technology Development Laboratory (TDL). It is assigned to you so that you may keep a complete, careful, chronological record of your work. The work which you do and the data which you enter in this book are confidential; they must not be disclosed to unauthorized persons. The logbook's security and maintenance are your responsibility. In case of damage, loss or

5.0 Procedure (continued)

disappearance, report the facts to your supervisor at once. When the logbook is filled, or upon termination of your employment, it must be returned to the laboratory quality/operation files.

5.3 Procedure

5.3.1 Briefly define in the front pages of the book what type of log is contained within. Definitions of column headings, references, and acceptance limits will be addressed on the first pages as well.

5.3.2 All entries are to be recorded directly into the logbook. Recording of original data on loose pieces of paper for later transcription into the logbook is to be avoided. Should loose paper be necessary for proper conduct of an experiment:

5.3.2.1 Write on the logbook page itself identification of what is affixed to that page

5.3.2.2 Firmly affix the loose paper with clear tape

5.3.2.3 Initial and date over the edge of the tape.

5.3.3 All entries must be made in black ink. Red ink is reserved for Quality Control (QC) checking purposes only. Erasures, blacking out, or use of correction fluid is not permitted. If a mistake is made, draw a single line through the erroneous material and make a corrected entry, initial, and date the correction.

5.3.4 It is necessary to fill each page and keep the sequence of entries in chronological order. Any unused section of a page will be cancelled with a diagonal line. Spaces intentionally left blank in tables or logs will contain horizontal lines.

5.3.5 When reference is made to samples, the TDL sample number will be used. Additional sample identification may be offered, but not to the exclusion of the TDL sample number.

5.3.6 Use a ruler to draw lines defining columns. Label columns including units when appropriate. Injection logs, balance logs, and other similar logs will include columns for the operators' initials and date.

5.3.7 Each entry in an analytical logbook is to be initialed and dated. The "Completed by" is signed by the last person to make entry on a given page and indicates that the page has been checked for completeness of entries.

6.0 Nonconformance and Corrective Action

6.1 A nonconformance is a deficiency in procedure sufficient to render the quality of an item unacceptable or indeterminate or any event which is beyond the limits documented and established for laboratory operation. A nonconformance may include data recording errors, transcription errors, and failure to document. A nonconformance memo associated with this procedure will be filed with the QC Coordinator.

7.0 Records Management

7.1 TDL Analytical Logbooks are the property of IT Corporation.

7.2 Document control of TDL Logbooks is handled by the QC Coordinator (QCC). The QCC will issue all notebooks. All completed logbooks will be returned to the QCC.

7.3 All returned Laboratory Logbooks are filed in TDL Central Files.

INTERNATIONAL TECHNOLOGY CORPORATION

IT Analytical Services

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Technology Development Laboratory Standard Operating Procedure

Title: STANDARD LABORATORY SIEVES : SPECIFICATION, CALIBRATION, AND MAINTENANCE

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Key Words: Sieve, ASTM E 11-87, Geotechnical

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LABORATORY SIEVES
SPECIFICATION, CALIBRATION, AND MAINTENANCE

1.0 Purpose and Application

1.1 This SOP defines the standards for standard laboratory sieves used in the Geotechnical Analysis Laboratory. It also describes calibration requirements and maintenance of the sieves.

2.0 References

2.1 ASTM E 11-87, Standard Specification For Wire Cloth Sieves For Testing Purposes.

3.0 Associated SOPs

3.1 None.

4.0 Definitions

4.1 None.

5.0 Procedure

5.1 All standard sieves will meet the specifications in ASTM E 11-87, Standard Specifications for Wire Cloth Sieves For Testing Purposes. Upon receipt, each sieve will be checked for a label which has the ASTM specification, sieve size, and a identification number or serial number. If the ASTM specification is not on the sieve, that sieve will be returned to the vendor and not used. If the sieve size or a serial number is not on the label, prepare a permanent label with the appropriate information and affix it to the side of the sieve. Due to the corrosive nature of some samples, brass sieves with stainless steel mesh are preferred.

5.2 Sieves put into use prior to this SOP do not require a serial number.

5.3 Calibration certificates should be provided by the manufacturer. If a calibration certificate did not come with the sieve, either return it, or get a certificate from the vendor. Calibration certificates will be kept in the Quality/Operations files maintained

by the lab QC Coordinator.

5.4 If a sieve calibration is suspect, it shall be either checked or replaced. Due to the amount of time involved in checking sieve calibration, replacement is usually the preferred alternative. AASHTO proficiency samples may also be used as an indication of sieve calibration. If the results from a proficiency sample are too far out of line (as determined by the lab supervisor), the suspect sieve shall be pulled for calibration or replacement.

5.5 Sieves with a mesh size of #200 or smaller will be replaced one year after initially being placed into service. Each sieve will be labeled with the replacement date at the time it is placed into service.

5.6 Prior to use, each sieve will be visually inspected for holes, broken mesh, or any other condition which may make the sieve unsuitable for use. Sieves which are clogged will be cleaned with a suitable brush. Caution shall be used when cleaning fine sieves with a wire bristle brush as this may damage the sieve. Any sieve deemed unsuitable for use will be immediately discarded.

5.7 Sieves used in washing samples or sieves used with corrosive samples will be cleaned with water and a brush after use. It may be useful to place the sieve in a drying oven (<120 °C) to dry. This will help to keep corrosion to a minimum.

5.8 Sieves will be stored in a clean, dry environment.

6.0 <u>Nonconformance and Corrective Action</u>

6.1 Sieves which do not meet the required specifications, are damaged, or otherwise unsuitable for use will be discarded or returned to the vendor if newly purchased. If a sieve is discovered nonuseable during use, the sample(s) will be retested and a nonconformance memo generated to describe the problem with the sieve and the fact that the sample(s) are being retested.

7.0 Records Management/Documentation

7.1 Sieve calibration records will be kept in the Quality/Operations files by the QA coordinator.

International Technology Corporation

IT Analytical Services

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Technology Development Laboratory Standard Operating Procedure

Title: CALIBRATION OF THERMOMETERS

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Key Words: CALIBRATION, THERMOMETER, NBS

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1.0 Purpose and Application

1.1 The purpose of this SOP is to detail proper procedures for the calibration of all laboratory thermometers, such that temperature measurements are accurate and traceable.

1.2 This procedure applies to any thermometer used in the laboratory directly or indirectly in the preparation, storage or analysis of samples.

1.3 Working thermometers in the laboratory shall be calibrated annually against reference thermometers that have initial NBS traceability and that are recertified every three years with equipment directly traceable to the NBS.

2.0 References

2.1 ITAS-SW SOP No. MW104R0, "Calibration of Thermometers."

3.0 Associated SOPs and Applicable Methods

3.1 ITAS System Procedure No. 9014-HSC-01, "General Health and Safety Practices for Tasks Performed in the Laboratory."

4.0 Definitions

4.1 None.

5.0 Procedure

5.1 Copies of the NBS traceable certification of reference thermometers will be kept in the Quality/Operations files.

5.2 Every three years reference thermometers will be recertified with equipment directly traceable to the NBS. A record of the date of this certification will be kept in the Equipment Maintenance and Calibration files by the QCC.

5.3 Each working thermometer in use in the laboratory will be assigned a unique number and will be calibrated annually against a reference thermometer using the calibration methods listed below as appropriate for the specific use of the thermometer:

5.0 Procedure (continued)

5.3.1 Calibration Method 1:

5.3.1.1 Working thermometer and reference thermometers are allowed to remain together in the same room for at least 24 hours. The bulbs are then put together on desk top for at least 30 minutes and read.

5.3.2 Calibration Method 2:

5.3.2.1 A one-liter beaker is filled with regular refrigerator ice cubes prepared with deionized water. The remainder of space in beaker is filled with deionized water. The working thermometer and reference thermometer are immersed with bottom of bulbs at same level. Wait at least 30 minutes and read.

5.3.3 Calibration Method 3:

5.3.3.1 Fill a one liter glass beaker with deionized water and bring to a boil on a hot plate. The working and reference thermometer are immersed with bottom of bulbs at same level. At least the whole bulb on each thermometer must be completely immersed. Wait 5 minutes and read.

5.3.4 Calibration Method 4:

5.3.4.1 Working thermometers and a reference thermometer are allowed to remain together in a freezer for at least one hour. After one hour, read the thermometers.

5.4 A Thermometer Calibration form (Figure TDL102-1) shall be completed for each working thermometer calibrated and placed in the Quality/Operation files.

5.5 Any thermometer that does not meet the acceptance criteria (± 1°C) shall be tagged to prevent inadvertent use. New thermometers that do not meet the acceptance criteria will be sent back to the vendor. Old thermometers that do not meet the acceptance criteria will be removed from the lab.

5.6 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

6.0 Nonconformance and Corrective Action

6.1 Any thermometer that does not meet the acceptance criteria (± 1°C) shall be tagged to prevent inadvertent use. New thermometers that do not meet the acceptance criteria will be sent back to the vendor. Old thermometers that do not meet the acceptance criteria will be removed from the lab.

7.0 Records Management

7.1 A Thermometer Calibration form (Figure TDL102-1) shall be completed for each working thermometer calibrated and placed in the Quality/Operation files.

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FIGURE TDL102-1

ITAS TECHNOLOGY DEVELOPMENT LABORATORY

THERMOMETER CALIBRATION

Date: _____

Number of thermometer being calibrated: _____

Description of thermometer being calibrated: _____

_____

Date last calibrated: _____

Time since last calibration _____

Description of reference thermometer: _____

_____

_____

Calibration Method Number	Temperature Reading	
	Reference Thermometer	Thermometer Being Calibrated

Working range: _____

Acceptance criteria: _____ ± _____ °C

Signed: _____