Formerly Utilized Sites Remedial
Action Program (FUSRAP)

Maywood Chemical Company Superfund Site

ADMINISTRATIVE RECORD

Document Number

MISS- 111.

US Army Corps
of Engineers®

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MAR 17 1998

James Signorelli
711 Maywood Avenue
Maywood, NJ 07607-1507

Subject: Transmittal of Report on Results of a Soil Washing Demonstration

Dear Mr. Signorelli:

To replace the copy you gave Tony Olivo at the last CGG meeting, I have enclosed a copy of the *Results of a Soil Washing Demonstration Project for Low-level Radioactively Contaminated Soil,* June 1996.

Sincerely,

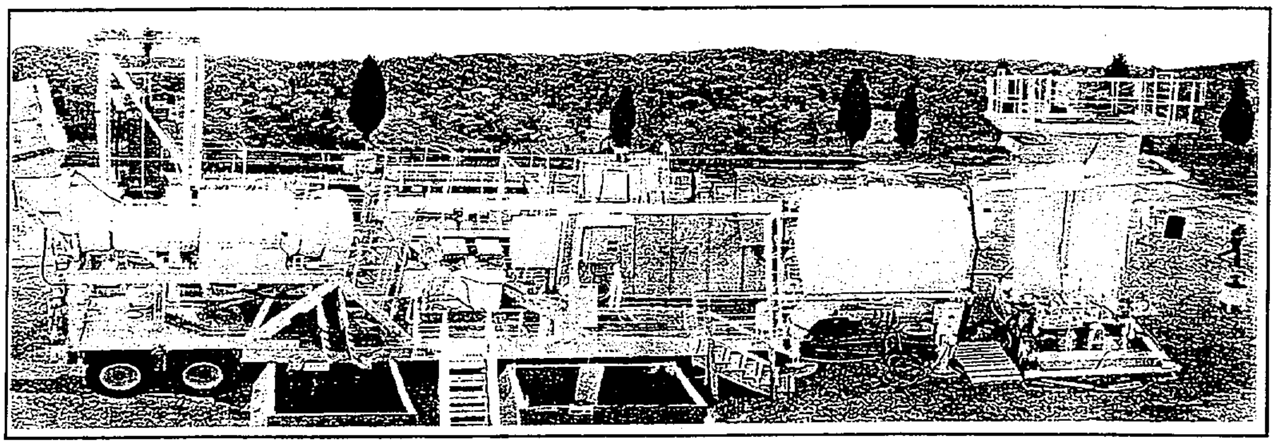
S. G. Wilkinson, PE
Project Manager - FUSRAP

SLS:csc:NJ98L041.DOC

M-704

DOE/OR/21949-404
JUNE 1996

Results of a Soil Washing Demonstration Project for Low-Level Radioactively Contaminated Soil



U.S. Department of Energy

Formerly Utilized Sites Remedial Action Program

FUSRAP

DOE/OR/21949-404

RESULTS OF A SOIL WASHING DEMONSTRATION PROJECT

FOR

LOW-LEVEL RADIOACTIVELY CONTAMINATED SOIL

June 1996

Prepared for

United States Department of Energy
Oak Ridge Operations Office
Under Contract No. DE-AC05-91OR21949

By

Bechtel National, Inc.
Oak Ridge, Tennessee

Bechtel Job No. 14501

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ACRONYMS

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
LMES	Lockheed Martin Energy Systems
MISS	Maywood Interim Storage Site
NAREL	National Air and Radiation Environmental Laboratory
NPL	National Priorities List
RCRA	Resource Conservation and Recovery Act
VORCE	Volume Reduction/Chemical Extraction (pilot plant)

UNITS OF MEASURE

cc	cubic centimeter
ft	foot
g	gram
gpm	gallons per minute
hr	hour
Hz	hertz
in.	inch
L	liter
lb	pound
µm	micrometer (micron)
pCi	picocurie
yd	yard

1.0 INTRODUCTION

The Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program and from commercial operations causing conditions that Congress has authorized the U.S. Department of Energy (DOE) to remedy. As part of its initiative to identify and evaluate cost-effective cleanup technologies, FUSRAP conducted a soil washing demonstration project using a VOlume Reduction/Chemical Extraction (VORCE) pilot plant developed by the U.S. Environmental Protection Agency (EPA).

Soil washing is a water-based physical treatment process in which contaminants are removed from soils based on separation of the soils into various particle sizes. Contaminants have an affinity for one particular size fraction of soil; removal of this fraction can produce a clean stream and a contaminated stream. The study was designed to allow DOE to gain operational experience with soil washing and to collect data on treatment performance and cost.

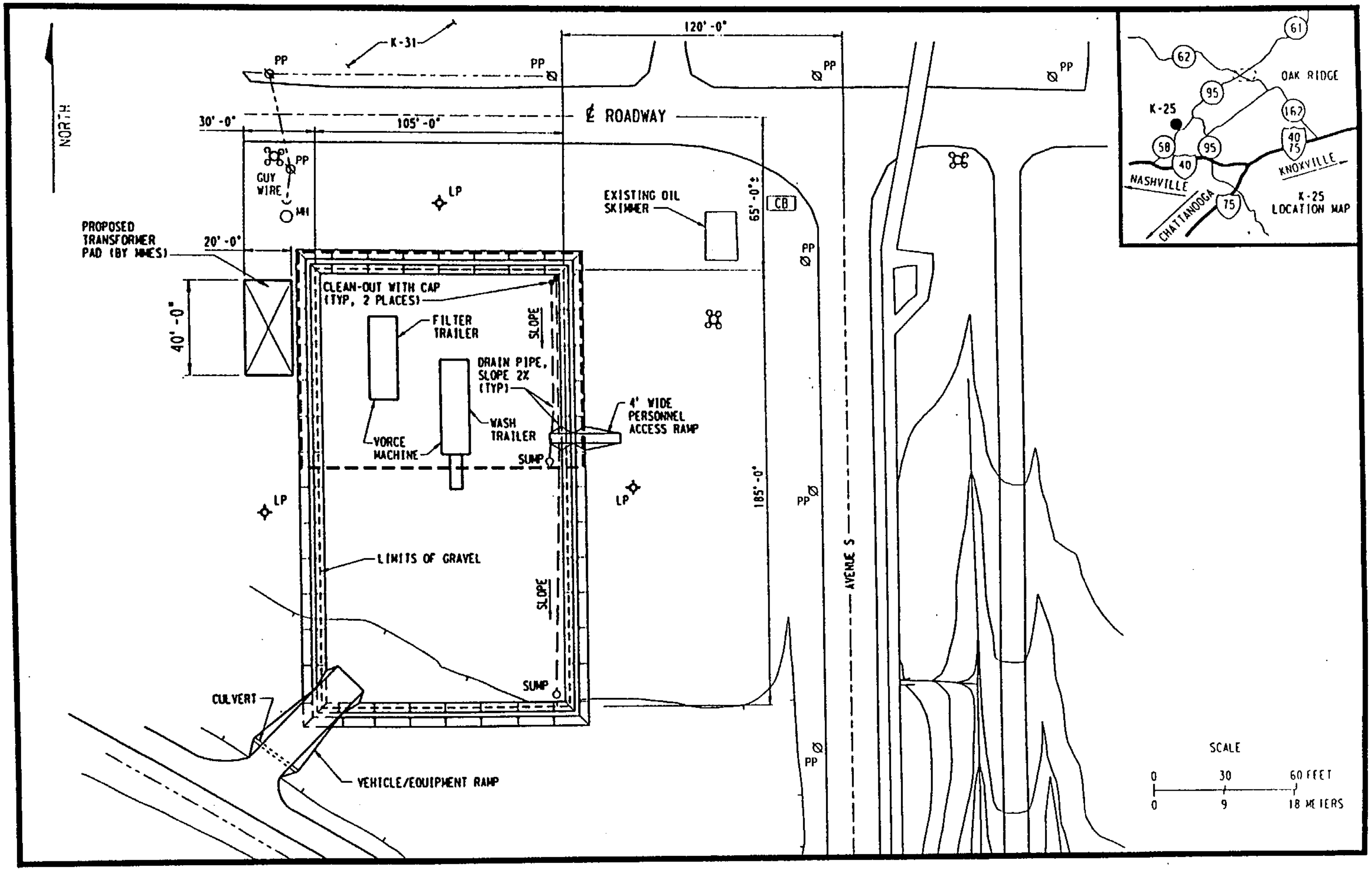
Three test campaigns were run on the VORCE machine during the demonstration project using (1) clean soil, (2) contaminated soil from the FUSRAP site in Maywood, New Jersey, and (3) contaminated soil from a Lockheed Martin Energy Systems (LMES) site in Oak Ridge, Tennessee. This report summarizes the results of the tests. Appendixes A through D contain the raw data obtained during the tests; copies of these appendixes are available on request.

2.0 BACKGROUND

The VORCE pilot plant was originally designed and constructed by EPA for potential use at the Montclair and Glen Ridge (New Jersey) Superfund sites, both of which are contaminated with radium-226. The pilot plant was subsequently made available for demonstrations at other Superfund sites. It was determined that soils from FUSRAP's Wayne and Maywood sites in New Jersey were candidates for the pilot tests because EPA characterization data existed showing the potential to apply soil washing as part of the remedial action at these sites.

The soil washing tests were performed at the K-25 site in Oak Ridge, Tennessee (Figure 1) through the LMES Center for Environmental Technology. The K-25 site was developed for uranium enrichment to support the Manhattan Project. Production of enriched uranium ceased in the early 1980s, and the emphasis of plant operations was shifted to environmental restoration.

The Center for Environmental Technology has a charter to bring new technology to the Oak Ridge facilities and had the permits necessary to perform the soil washing tests. The soil washing pilot project helped the center meet its goal of performing demonstrations to evaluate technologies that may be applicable to the site. Contaminated soils from one of the LMES sites was included in the study as part of a cooperative agreement between the State of Tennessee and LMES for the use of the K-25 facility.


NORTH
K-31
PP
120'-0"
℄ ROADWAY
30'-0"
105'-0"
GUY WIRE
MH
LP
EXISTING OIL SKIMMER
65'-0"
CB
PROPOSED TRANSFORMER PAD (BY MMES)
20'-0"
40'-0"
CLEAN-OUT WITH CAP (TYP, 2 PLACES)
FILTER TRAILER
SLOPE
DRAIN PIPE, SLOPE 2% (TYP)
VORCE MACHINE
WASH TRAILER
SUMP
4' WIDE PERSONNEL ACCESS RAMP
185'-0"
AVENUE S
LIMITS OF GRAVEL
CULVERT
VEHICLE/EQUIPMENT RAMP
61
62
95
OAK RIDGE
K-25
162
58
40
40
75
NASHVILLE
KNOXVILLE
CHATTANOOGA
75
K-25 LOCATION MAP
SCALE
0
30
60 FEET
0
9
18 METERS

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A large grassy area south of the K-31 building at the K-25 site was prepared for the VORCE pilot test. Site preparation activities included removing the grass and soil, constructing a berm around the area, and installing a series of liners and a gravel pad to contain potential spills and rainwater runoff. A double liner was placed under the process area and a single liner under the staging/storage area. The liner material is 40 mil polypropylene with welded seams. A gravel pad was placed below the liner as a foundation, and more gravel was placed on top of the liner. The lined area has two sumps: one for rainwater and one for potential process spills. The sump and collection system is designed to segregate rainwater, which could normally be discharged, and process spills, which might require processing before discharge.

3.0 TEST OBJECTIVES

The objectives of the VORCE and soil washing tests in general were:

1. Determine the mass reduction achieved using the soil washing process and whether the clean streams meet the cleanup standard of 5 pCi/g of thorium-232. Laboratory studies found that contaminants were attached to small soil particles (fines) and that laboratory techniques could be used to separate sufficient fines from the oversized particles to achieve a mass reduction between 65 and 70 percent in the contaminated soil. The goal of the soil washing demonstration was to track within 90 percent or greater of this value (i.e., 59 to 63 percent or greater mass reduction).

   Note: The terms *volume reduction* and *mass reduction* are often used interchangeably; however, mass reduction is the correct terminology. Volume reduction refers to the in situ volume to be disposed of. When soil is removed for treatment, the volume swells (often as much as 30 percent), and as the soil is treated, the volume may vary as a function of moisture content or other properties. Because of the difficulty in measuring volume, laboratory and field work are based on measurements of mass.

2. Identify health and safety issues associated with plant operation in regard to workers and the local community.

3. Determine whether operation of the plant has any additional potential impacts on workers and the community or requires extraordinary measures to protect the workers and the community.

4. Estimate cleanup costs for a full-scale soil washing plant for comparison with other remedial options.

5. Determine whether there is potential for the contaminated waste stream to be classified as either hazardous waste, as defined by the Resource Conservation and Recovery Act (RCRA), or mixed waste.

6. Debug the system and obtain operating experience.

7. Evaluate the performance of individual unit operations and optimize the system.

8. Recommend process modifications to improve full-scale performance.

9. Provide stakeholders an opportunity to observe the system on a pilot scale.

4.0 MAYWOOD SITE DESCRIPTION

The Maywood site was assigned to DOE by Congress through the Energy and Water Development Appropriations Act of 1984 and was subsequently designated for cleanup under FUSRAP. In 1983, the Maywood site was added to the EPA National Priorities List (NPL).

The Maywood Interim Storage Site (MISS) is located in the Borough of Maywood and the Township of Rochelle Park in Bergen County, New Jersey. The site occupies approximately 11.7 acres in the densely industrialized northeastern portion of the state, approximately 12 miles north-northwest of New York City and 13 miles northeast of Newark, New Jersey (Figures 2 and 3)

Maywood Chemical Works was constructed on the site in 1895. The facility produced rare earths, detergents, alkaloids, essential oils, and lithiated compounds. In 1916, the plant began extracting thorium and rare earths from monazite sand for use in manufacturing industrial products such as mantles for gas lanterns. The manufacturing process included the production of mantle-grade thorium nitrate from monazite sands and various lithium compounds, especially lithium hydroxide and lithium chloride. After 1954, thorium products suitable for purification to Atomic Energy Commission reactor-grade levels were produced. Figure 4 shows the thorium extraction process used by Maywood Chemical Works as it is understood today. Thorium extraction stopped 1956, but thorium processing of stockpiled material continued until 1959.

Slurry containing process waste from the plant was pumped into two areas surrounded by earthen dikes on property west of the plant. In 1932, the disposal areas were separated from the plant and partially covered during construction of Route 17. Some process wastes were removed and used as fill on nearby properties. Additional waste migrated off the property via natural drainage.

The total volume of contaminated soil at the Maywood site is approximately 375,000 yd^3. Of this total volume, approximately 35,000 yd^3 has been removed from vicinity properties during previous cleanup activities and placed in interim storage at MISS. At the end of July 1995, approximately half of the interim storage pile had been removed and disposed of at the Envirocare disposal facility in Clive, Utah; the rest is scheduled to be removed by the end of 1996.

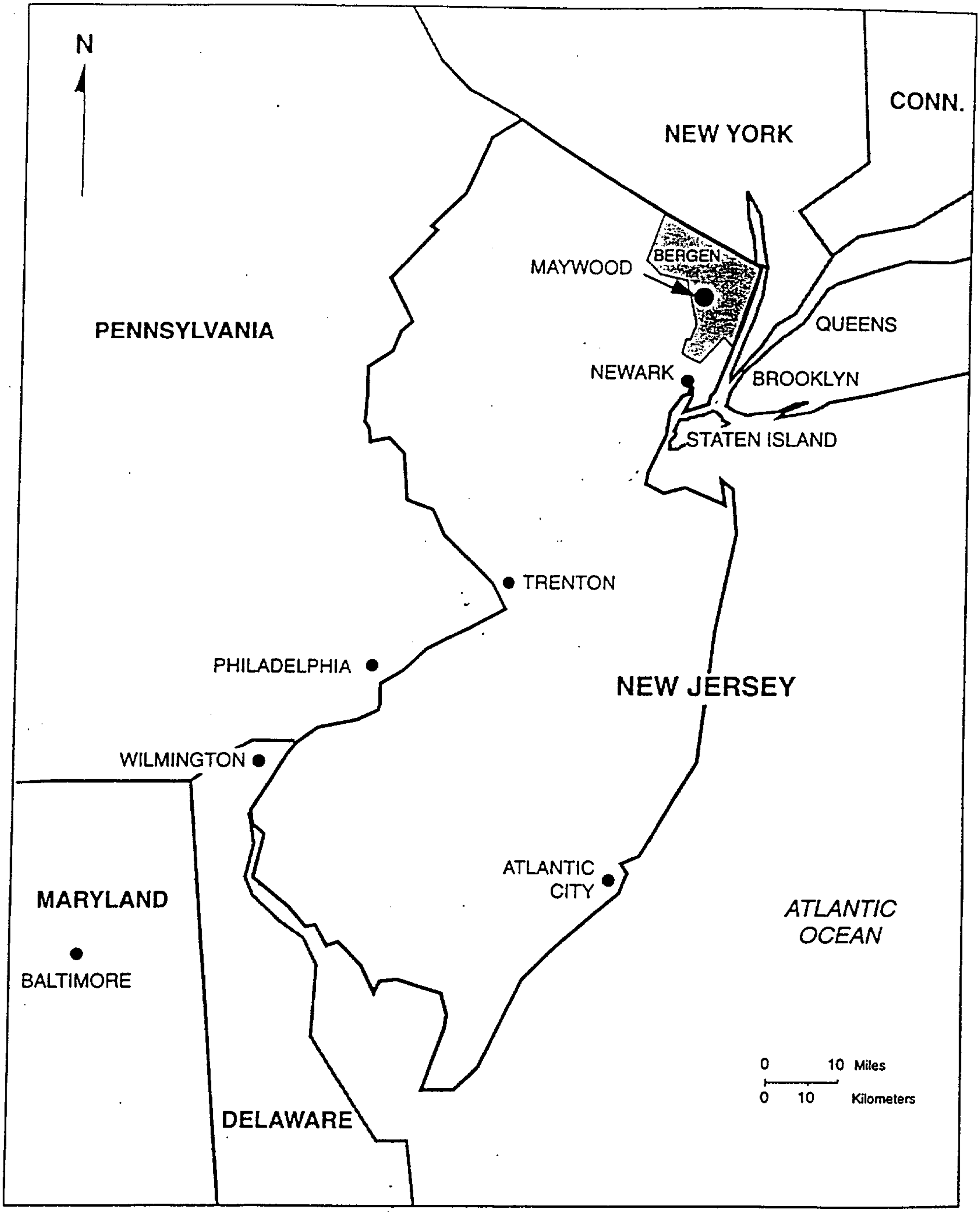


Figure 2
Location of Maywood, Bergen County, New Jersey

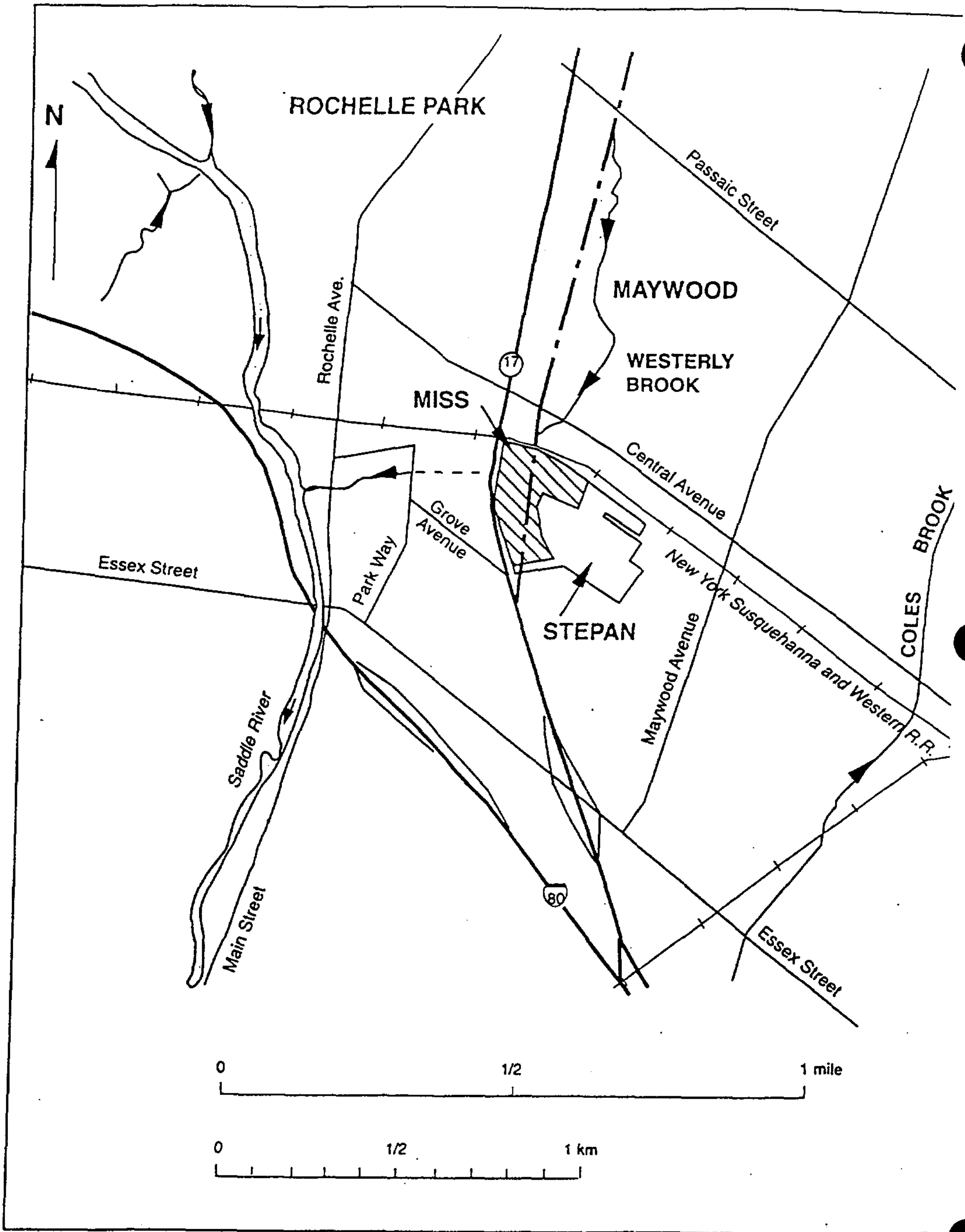
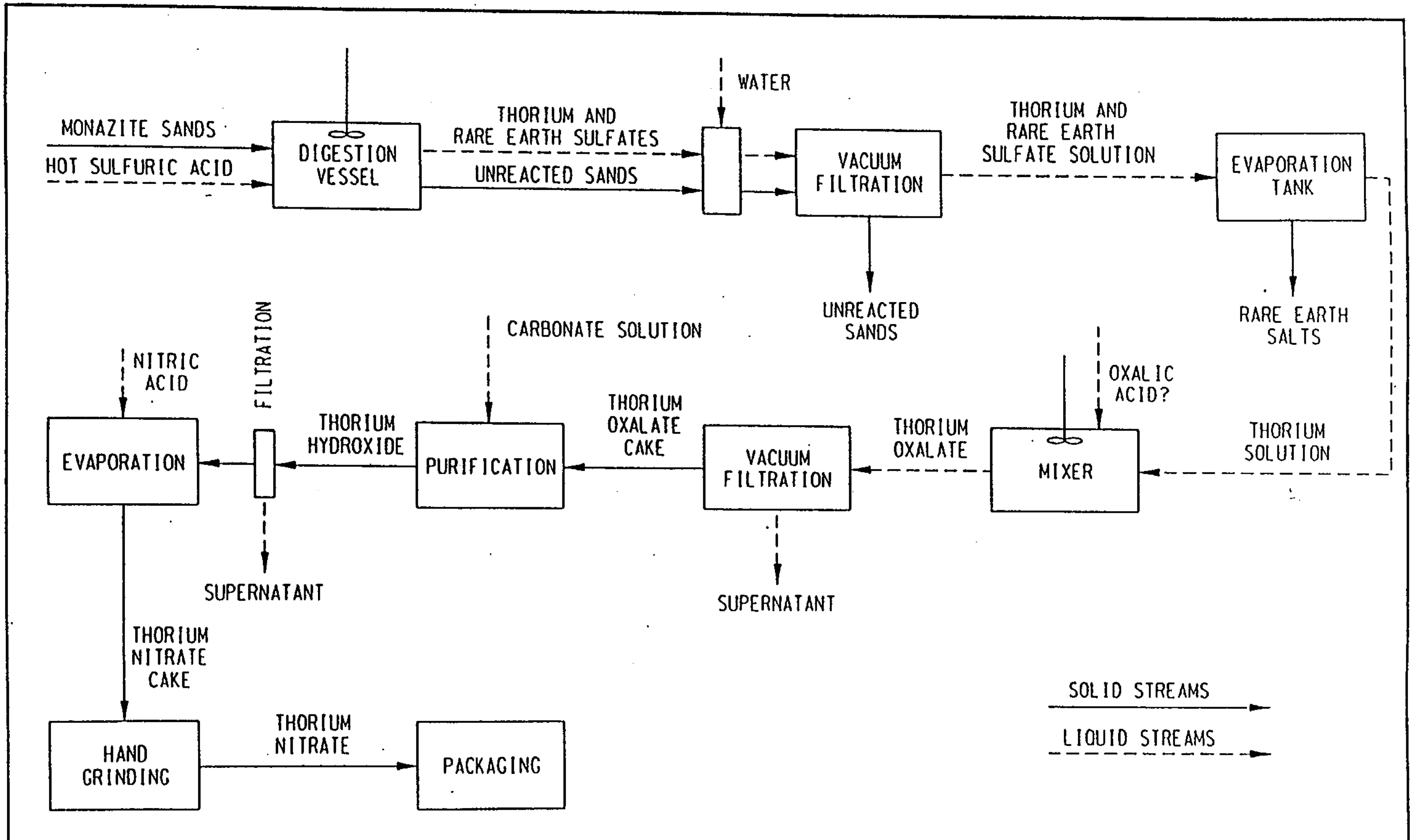


Figure 3
Location of MISS



* ADDITIONAL PROCESS INCLUDED CONVERSION OF THORIUM HYDROXIDE TO THORIUM CHLORIDE WHICH WAS SOLD AS AN INTERMEDIATE PRODUCT. THORIUM HYDROXIDE WAS FORMED AGAIN AND NITRIC ACID WAS ADDED TO PRODUCE THORIUM NITRATE. (*SOURCE*: ATOMIC ENERGY COMMISSION COMPLIANCE INSPECTION REPORT DATED 5/24/57.)

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Figure 4
Process Possibly Used to Produce Mantle-Grade Thorium Nitrate at Maywood Chemical Works

The contaminants of concern at the Maywood site and their average concentrations in the pi are thorium-232 at 18.1 pCi/g, radium-226 at 2.4 pCi/g, and uranium-238 at 17 pCi/g. Analytical data indicate that the material in the pile does not exceed regulatory limits that define a RCRA-hazardous waste.

4.1 ANALYSIS OF MAYWOOD SOILS

The most abundant radionuclides in the soil at Maywood are thorium-232 and its decay products; uranium-238 and its decay products are also present. The radionuclide concentrations ai not evenly distributed throughout the site. The EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, performed analytical tests to determine whether t Maywood soils were candidates for soil washing treatment. The following are some of the more significant findings from these tests:

- The major source of radioactivity in the sand and silt-size particles is monazite. Zircon is also present and contributes a small amount of radioactivity. Three samples contained calcium-thorium orthophosphate, an industrial process waste, that contributed appreciable radioactivity two of the samples.

- Monazite and zircon in these samples are essentially insoluble in water. The magnetic susceptibility of monazite is in the intermediate range, while that of zircon is low. Other particles with high specific gravity have generally higher magnetic susceptibility than monazit and zircon. Because the contaminants are not soluble in the water used for soil washing, magnetic removal is not a potentially viable treatment option.

- The average specific activity of the soil particles is 2.6 g/cc, compared to 4.7–5.4 g/cc for monazite and zircon, indicating that density separation could be used a treatment option.

- Material adsorbed on the particle surfaces probably accounts for most of the radioactivity in th clay-size particles. Chemical precipitates of thorium from the thorium extraction process are also present and contribute to the radioactivity in the sample. Adsorption of the contaminants the clay particles and their concentration in the silt/clay fraction indicate that removal of this fraction from the soil could produce a clean stream.

- The fine sand, silt, and clay-size particles can be removed from all but two of the soils tested, resulting in the separation and collection of up to 70 percent of the original material using physical treatment processes alone.

These findings indicate that physical treatment can reduce the mass of contaminated mater by 65 to 70 percent of the original material. Particle size separation and density separation techniques can be used to obtain these results. The VORCE machine is capable of producing those types of particle size cuts.

4.2 CONCEPTUAL DESIGN AND ECONOMIC ANALYSIS

Laboratory results showed that contamination in the Maywood soil was associated with small mineral fractions attached to the silt/clay fractions of the soil. Removal of those fractions should produce a significantly large clean fraction and a smaller contaminated fraction.

The U.S. Bureau of Mines Albany Research Center in Albany, Oregon, used the data from the NAREL characterization studies of pile samples to develop a conceptual design and economic analysis for a soil treatment process. The design developed by the Bureau of Mines mirrored the process used for the VORCE system. The only variations in the designs were in specific unit processes used to obtain the desired size cuts.

A general description of the process units is as follows: a trommel for initial deagglomeration, a classifier to force a coarse sand cut, an attrition mill to remove adhered clays from the sands, another classifier to remove the fines removed from the sands by attrition scrubbing, a gravity separator to remove the heavy concentrated fraction, a series of hyrdrocyclones to make a fine sand cut, and a clarifier and centrifuge to remove fines and recycle the water. Gravity separation was not considered necessary because of the low percentage of heavy minerals present. The economic analysis showed that the cost would be approximately $250/yd3 ($192/ton).

5.0 VORCE PROCESS

5.1 TREATMENT APPROACH

The VORCE machine separates soils by particle size using equipment most often found in the mining industry, such as trommels, vibratory and static screens, attrition mills, screw classifiers, hydrocyclones, hydraulic classifiers, clarifiers, and filters. This kind of equipment has been used in the separation of mineral products from soils for over 100 years, but until recently the technology had not been applied to environmental restoration activities. The process is based on the fact that some types of contaminants attach themselves to one particle-size fraction of the soil (normally the fines), and removal of this fraction from the other size fractions will produce a clean product. The following particle-size cuts of the feed soil were made: 1/4 in. and greater, 250 μm to 1/4 in., 75 μm to 250 μm, and 75 μm and less.

5.2 EQUIPMENT AND PROCESS DESCRIPTION

Figure 5 shows the flow diagram for the soil washing machine. During the VORCE process, contaminated soil is emptied onto a static grizzly screen to remove particles greater than 2 in. The undersize material passes through the screen, and the oversize material is removed for separate cleaning. The undersize material then enters a feed hopper and is discharged onto a drag flight conveyor. The conveyor transports the soil into a scrubber/trommel screen. Two operations occur the trommel screen: (1) deagglomeration and (2) washing of the gravel to remove fines. The trommel has a scrubber chamber and a screen chamber. Gravel is washed in the scrubber chamber by physical movement, a water pool, and water sprays. The washed gravel overflows a dam into th screen section. The gravel is rinsed in the screen section, and the fines less than 1/4 in. pass throug Particles larger than 1/4-in. gravel overflow into a collection bin as clean product.

The fines fraction (less than 1/4 in.) is collected in a primary classifier where separation occu based on Stokes' Law, which states that a particle in a fluid will settle at a rate proportional to the size and density of the particle (i.e., larger particles settle faster than smaller particles). An upward current of water enhances the size cut by providing resistance to the settling soil. The overflow material (less than 250 μm) is discharged over a weir into a collection sump. The coarse material settles to the bottom and is dewatered. This material is then discharged into an attrition mill, where opposing propellers force particle-to-particle abrasion, thereby removing attached fines. The material discharged from the attrition mill enters the secondary classifier where the previously described classification process is repeated. The oversize material from the secondary classifier is discharged as clean product.

The fines are collected in the same sump as the primary classifier overflow and are fed to the cyclone (hydrocyclone). The cyclone makes a fine cut of 200 mesh (75 μm) and dewaters the feed to the next unit operation. The fines overflow is collected in another sump, and the coarse underflo is fed to the hydrosizer (hydraulic classifier), which performs a fine cut between 200–325 mesh (75-45 μm). The cyclone performs separations based on centrifugal force, while the hydrosizer use a combination of Stokes' Law and hindered settling to make the cuts. The fines collected from the hydrosizer are collected in the same sump as those from the cyclone. The coarse underflow fractio is fed to a dewatering screen, and the screen oversize is collected as a clean product. The fines and water from the screen are collected in the same sump as the other fines fractions. These fines are flocculated using polymer and fed to a clarifier. The flocculated fines are collected in the bottom o the clarifier, and the clear water overflows into the process make-up water tank. The water in this tank is recycled during the VORCE process.

The sludge in the bottom of the clarifier is pumped to a holding tank before it is fed to a filter press for final dewatering. The filtrate is recycled to the clarifier for reuse. The filter cake contains the contaminated fines.

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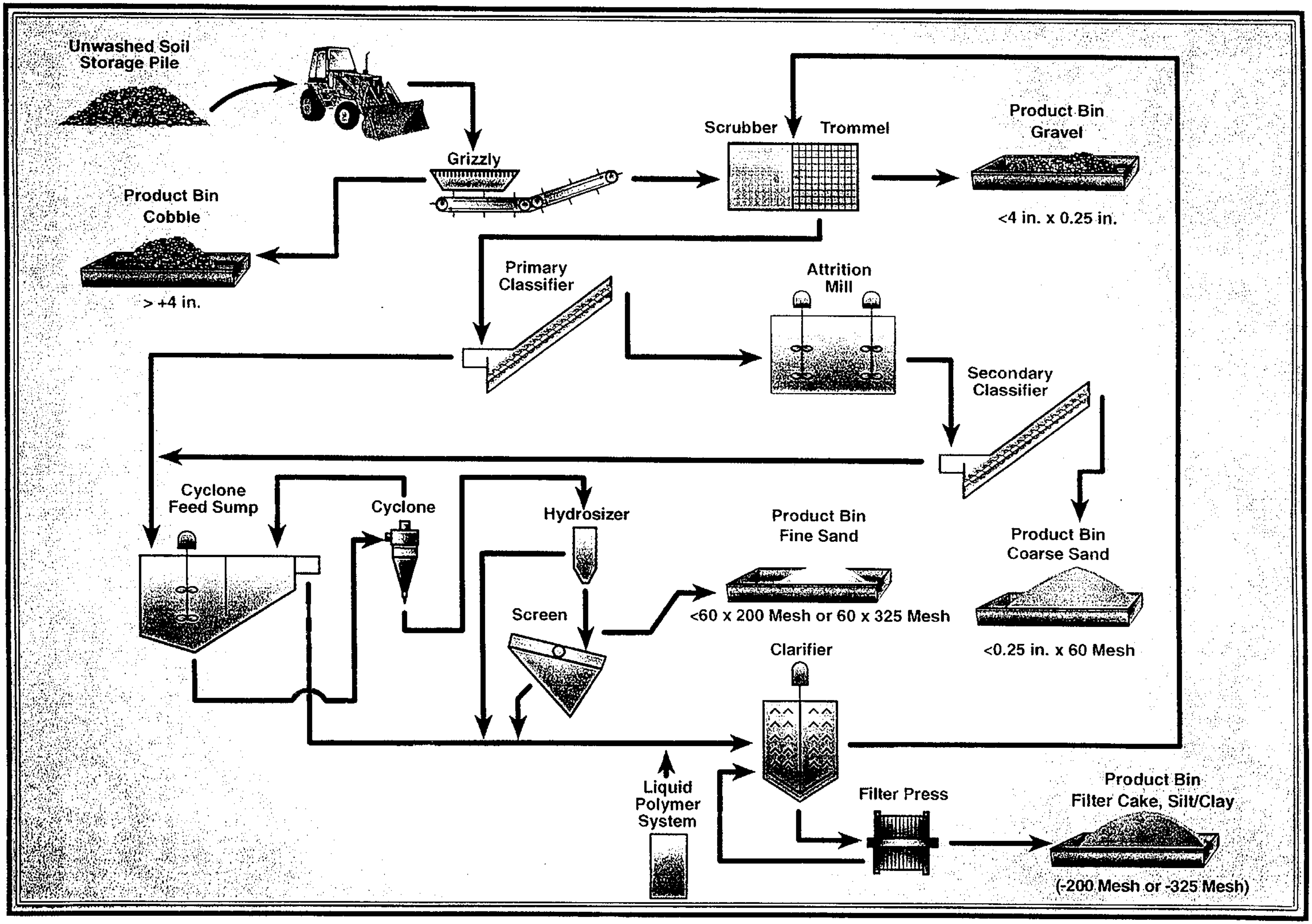

Figure 5
Soil Washing Plant Flow Diagram

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6.0 CLEAN SOILS TESTS

The VORCE machine, as originally obtained from EPA, required modification to improve operating performance. These modifications included eliminating screw conveyors and replacing them with direct feed from unit operation to unit operation, adding the hydrosizer to aid in producing a fine cut, and eliminating replicate equipment to keep system unit operation sizes consistent. After the modifications were made, the machine was tested using clean soils to evaluate the results of the modifications. The clean soils provided an opportunity to test the system without the restrictions associated with processing radioactively contaminated soil.

Seven different types of clean soils were tested:

- two 60+ percent sands,
- a clayey soil,
- a silty soil,
- two blends with organic matter, and
- a Maywood surrogate.

Preliminary data indicated that these soil types would cover the range of FUSRAP soils that might be processed with the VORCE machine. A total of 90 tons of clean soil was processed during fiscal year 1995. The clean soil tests provided valuable information on operational aspects of the pilot plant, including identification of soil types and characteristics that the machine can process. The VORCE machine, unlike industrial machines, is inflexible relative to configuration changes; therefore, many of the material-handling problems experienced during VORCE processing are unique to the machine itself and do not represent industry capabilities. The raw data from the tests are included in Appendix A. Some of the information obtained related to operation and materials handling is summarized below:

- Maximum feed rates for different soil types were identified.

- The effects of soil types on machine performance were identified.

- Process controls necessary to ensure a steady feed rate to the machine, as a function of soil type, were determined.

- It was determined that the addition of a hydrosizer taxed the system feed-water pump, and the pump would not operate when all water to the system was on. Eventually, the pump was replaced to alleviate this problem.

- Data indicate a missized cyclone feed pump caused a pressure drop across the hydrocyclone, which limited the ability of the machine to make a proper cut. The missized pump was not upgraded when the system was modified.

- Gravelly soil had the greatest throughput rate at 1.5 tons/hr; soils with high silt/clay content we fed between 800–1,000 lb/hr.

- Polymer demands and types changed as soil types changed.

6.1 OBJECTIVES OF THE CLEAN SOIL TESTS

The specific objectives of the VORCE pilot test were to

- debug the machine,
- train the operating crew to operate the machine,
- evaluate machine response to different soil types,
- develop generic settings for various soil types to obtain specified cuts (the generic settings were used to predict settings for contaminated soil operation),
- determine whether the machine could be operated safely and efficiently, and
- determine the time required for the machine to reach steady state.

Evaluation of the clean soil tests show that all of these objectives were met. The crew was trained and able to have the machine running within one hour after reaching the site. This was don without any major spills, leaks, or accidents. The types of soils that the machine could process were determined, and generic settings were established for starting the machine using these soil types. Responses to these soils were determined (i.e., time to reach steady state), and data were collected t develop partitioning curves around particular unit operations.

6.2 PARTITION CURVES

Data collected during the clean soil runs were used to generate partition curves around the various unit operations. The curves are a mass balance of the soil fractions around the particular ur operation and compare the actual particle-size cut point produced by each unit operation. The curv normally shaped as an S-curve, compares the fraction of fines reporting to the oversize. The cut point is the 0.5 fraction or 50 percent size that intersects the curve. Figure 6 shows typical partitior curves. These curves can be used by the operator to evaluate system and equipment performance o to provide information for adjusting the machine or particular unit operation to obtain the proper performance.

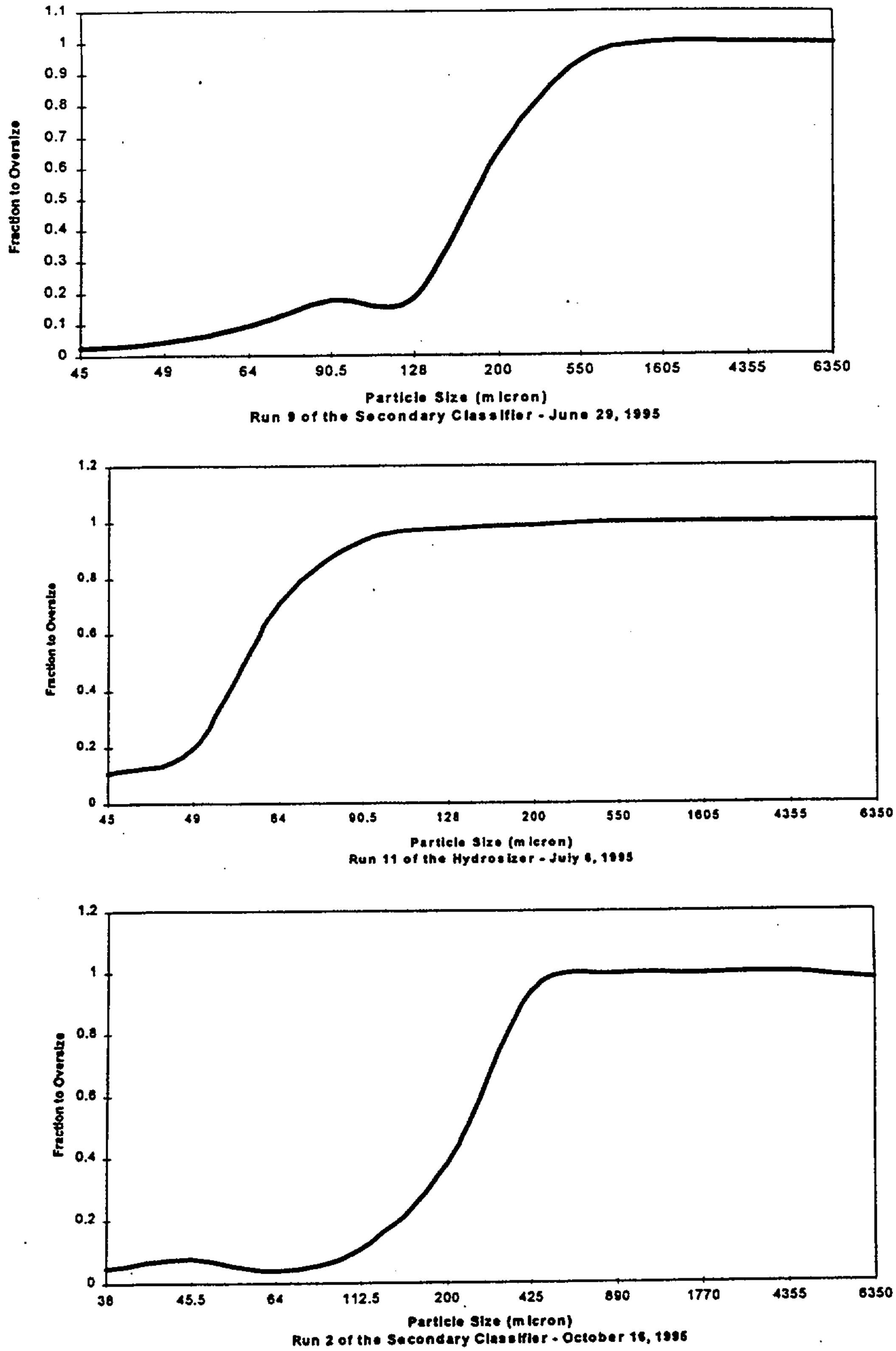


Figure 6
Partition Curves

Operational settings were tested for the various soils that were processed. These settings cou then be used to set up the machine for contaminated soil runs. Table 1 summarizes the settings tha were tested and the unit operations that were controlled.

7.0 MAYWOOD SOILS TESTS

Six intermodal containers, each containing approximately 16 tons of soil, were shipped from MISS to the K-25 site. The soil was collected from the MISS pile using standard excavation techniques. When the containers arrived in Oak Ridge, they were sampled and particle size analys was performed. The containers were staged outside the bermed area.

Soil from MISS was tested in the VORCE machine for two weeks, during which time 20 tons of soil was processed. The soil was processed at 0.5 ton/hr. Data were collected for one week of operation from October 24 through November 1, 1995. During the processing operation, one intermodal container at a time was brought inside the bermed area and the open end placed on temporary containment structure. The container was opened on the top and side for access by a backhoe/front-end loader. Gross oversize material (greater than 2 in.) in the soil was removed by hand before the soil was processed. Composite samples of the feed, greater than 1/4-in. fraction, 1/4-in. to 250-µm fraction, 250-µm to 75-µm, and less than 75-µm fraction were collected and analyzed for radionuclides and particle size. A mass balance was performed around the system to compare theoretical versus actual performance.

Figure 7 shows the average contaminant concentrations in the feed material and the concentrations found in each soil fraction after treatment. The data show that the fractions larger than 75 µm are below the release criteria of 5 pCi/g of thorium-232. A mass reduction of 63.8 percent clean material was achieved (see Figure 8 and Table 2), with 36.2 percent contaminated, including the oversized material that was not decontaminated. The oversized mater accounted for only 6 percent of the mass. A mass balance performed over the entire system shows mass accountability of 98.6 percent.

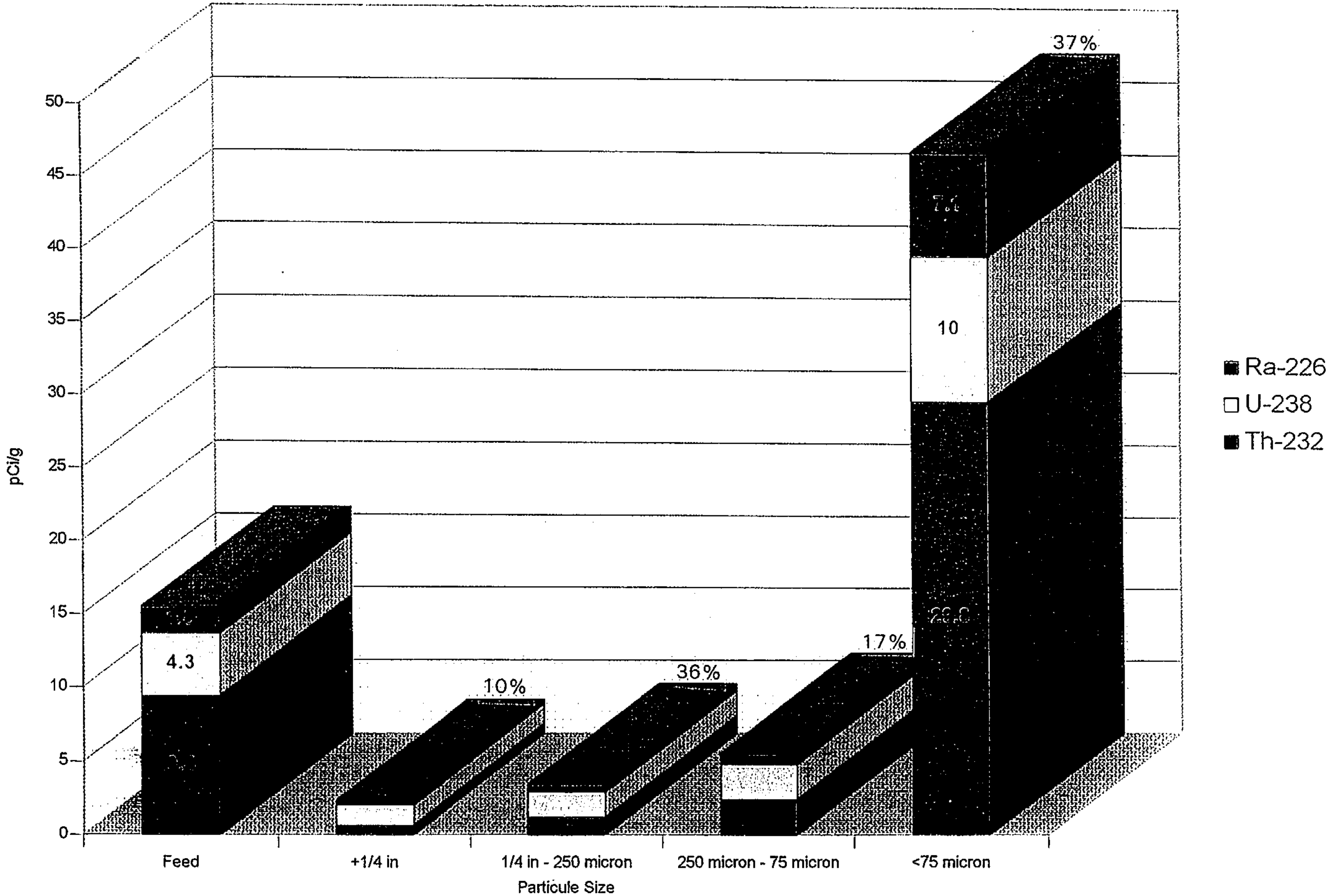
The system would be expected to perform similarly with high contaminant concentrations because soil washing is a physical process and is not dependent upon concentration. If properties (the soil show that the contaminants are attached to the fine silt/clay fraction, this fraction can be removed from the other fractions.

Analysis of the filter cake for toxicity characteristic leaching procedure (TCLP) metals shov that the concentrations of metals are below regulatory concern. Analysis of the process water showed that the radionuclides are insoluble in water and that the process water met the criteria for discharge into the K-25 Central Neutralization Facility.

Table 1

Settings for VORCE Based on Clean Soil Runs

Equipment	Adjustment	Function	Maywood Type Soil 1/4-in/60 mesh/ 200 mesh cut		Maywood Type Soil 1/4-in/60 mesh/ 270 mesh cut		Clay Type Soil 1/4-in/60 mesh/ 270 mesh cut	
			Settings	Units	Settings	Units	Settings	Units
Conveyor	Speed	Feed rate	6.5	Hz	6.5	Hz	8	Hz
Trommel	Rotational speed	Retention time	23.8	Hz	23.8	Hz	23.8	Hz
	Tilt	Retention time	4/6	in/ft	4/6	in/ft	4/6	in/ft
	Spray	Washing	11	gpm	11	gpm	3	gpm
	Elbow flush	Prevent plugging	5	gpm	5	gpm	15	gpm
Primary Classifier	Elutriation water	Settling rate	7	gpm	7	gpm	8	gpm
	Dilution water	Wash off fines	5	gpm	5	gpm	3	gpm
Secondary Classifier	Elutriation water	Settling rate	8	gpm	8	gpm	6	gpm
	Dilution water	Wash off fines	2.5	gpm	2.5	gpm	3	gpm
Hydrocyclone	Vortex diameter	Cut size	2.5	in	2.5	in	2.5	in
Hydrosizer	Teeter water	Settling rate	12.5	gpm	10	gpm	10	gpm
	Delta pressure	Bed density	10	psig	8	psig	8	psig



Note: Percentages show mass distribution by size fraction.

Figure 7
Contaminant Distribution in Maywood Soils

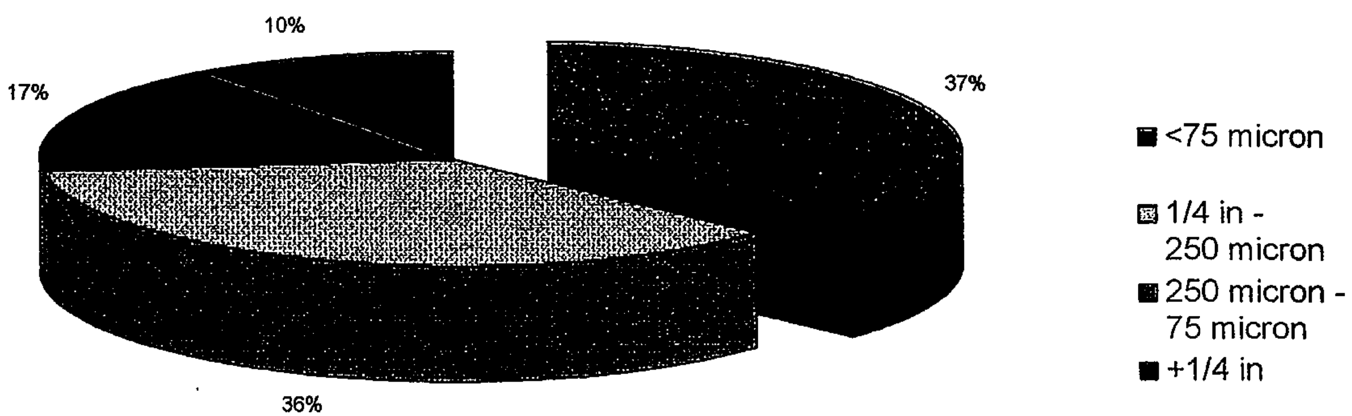


Figure 8
Particle Distribution in Maywood Soils

Table 2

Mass Balance Around VORCE Machine - MISS Soils

Stream Number	Steam name	Mass, lb.	Percent of Feed
1	Feed soil (contaminated)	28,336	NA
3	>1/4 in. (clean)	2,911.9	10.28
8	250 μm-1/4 in. (clean)	10,051	35.47
12	75 μm-250 μm (clean)	4,708	16.61
17	<75 μm (contaminated)	10,288.5	36.31
Mass Recovered		98.67%	
Mass Reduction		63.8%	

The tests were conducted using non-wetted soil fed directly from an intermodal container. A sampling data indicate that there were no emissions or dusts from the machine. The raw data from these tests are included in Appendix B.

Results of a noise profile performed around the machine during operations show that sound levels were below compliance criteria. Figure 9 shows sound levels at various distances from the test site during operation of the machine. Most of the higher sound levels are within the testing are As illustrated in Figure 9, sound levels decrease significantly with distance. At a distance of 10 ft from the machine, sound levels are below the industry standards requiring hearing protection, and a 200 ft, sound levels are the same as background.

When the tests were completed, the soil fractions were recombined and prepared for shipment to the Envirocare of Utah disposal facility. To ensure that the soil met disposal facility requirements, approximately 10 pounds of absorbent material was packaged in each intermodal container to absorb any water remaining from the processing operation. All of the Maywood soil was shipped to Envirocare for disposal because an agreement with the State of Tennessee required that no soil shipped from New Jersey could be left in Tennessee.

8.0 CSX SOILS TESTS

Approximately 250 tons of railroad ballast material contaminated with cesium-137 was removed from the CSX railroad tracks near the LMES Y-12 Plant as part of the environmental restoration effort on the Oak Ridge Reservation. This material included soil, gravel, and ballast and is commonly referred to as CSX soil. The material has been stored at K-25 awaiting disposal.

Characterization of the CSX soil showed that cesium-137 was concentrated in the fine particle size fraction. Results of the initial characterization are shown in Table 3. Removal/separation of th fines fraction containing cesium-137 could provide a significant reduction in the volume of soil requiring disposal. Small-scale laboratory tests indicated that mass reductions of greater than 80 percent could be realized using a particle-size separation technique such as soil washing.

Because of this potential for mass reduction, it was decided that a pilot-scale test on up to 25 tons of this material would be performed using the VORCE soil washer at the K-25 site. The clean-up criterion was 50 pCi/g of cesium-137. (The cleanup criterion was established for the removal action that generated the contaminated waste materials.) The concentration of cesium-137 in the CSX soil to be treated averaged 160 pCi/g; however, cesium-137 concentrations during the cleanup action ranged from 1.4 pCi/g to 2,400 pCi/g.

A total of 51,150 pounds of CSX soil was processed in the VORCE machine from November 2 to November 21, 1995. Figure 10 shows the average concentration of cesium-137 in

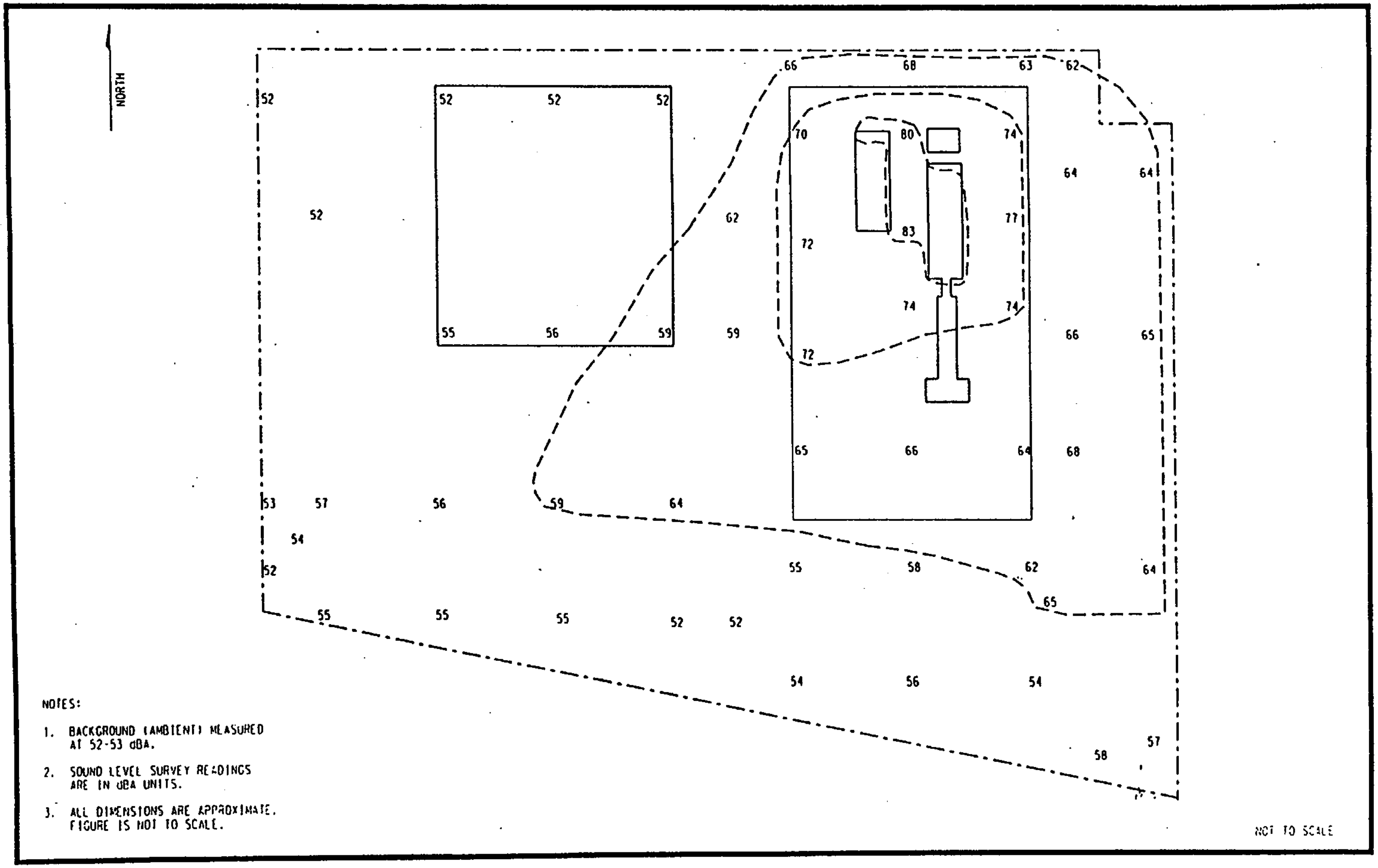


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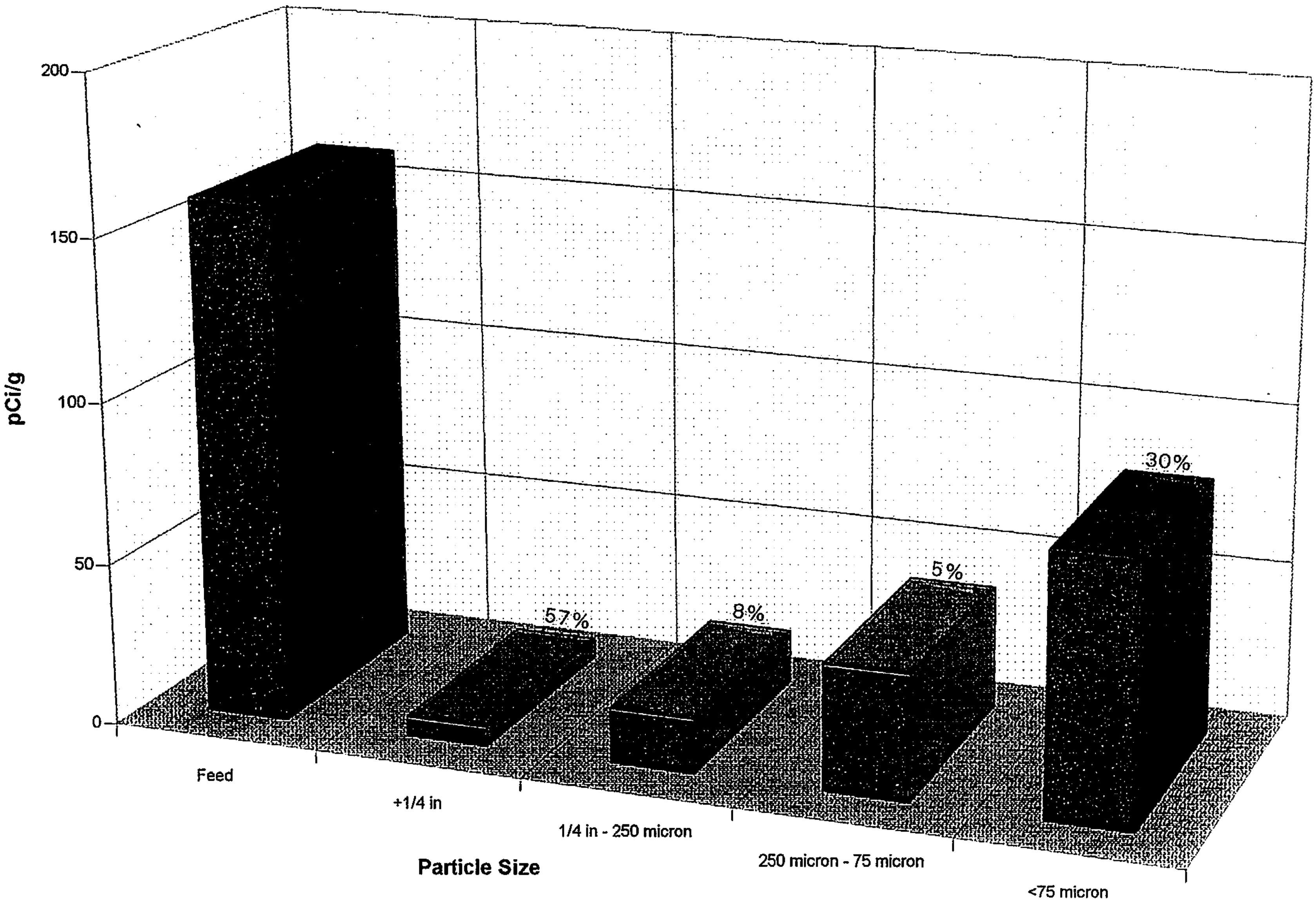
Figure 9
Sound Level Survey at the K-25 Soil Washing Site

Table 3

Initial Characterization Results for the Cesium-Contaminated Materials

Sample	Particle-Size Fraction μm	Particle-Size Distribution %	Cs-137 pCi/g	Cs-137 Burden pCi/g	Cs-137 Burden %
24.1A	>6300	85.3	4205.6	3589.4	96
	6300-850	2.8	190.3	5.4	<1
	850-150	2.1	708.5	14.6	<1
	150-45	1.0	1335.0	13.2	<1
	<45	8.8	1293.0	113.7	3
	Water		143.0 pCi/L		
24.1B	>6300	84.1	81.8	68.7	29
	6300-850	3.1	247.9	7.8	3
	850-150	0.8	1327.0	11.2	5
	150-45	1.0	1431.0	13.7	6
	<45	11.0	1226.1	134.8	57
	Water		42.5 pCi/L		
27.1A	>6300	72.6	0.1	0.1	5
	6300-850	11.8	1.0	0.1	6
	850-150	4.8	3.7	0.2	8
	150-45	1.8	9.2	0.2	8
	<45	9.1	17.3	1.6	74
	Water		BDL		
27.1B	>6300	74.2	0.3	0.2	7
	6300-850	9.0	2.0	0.2	7
	850-150	2.6	4.8	0.1	5
	150-45	2.2	9.0	0.2	7
	<45	12.1	16.7	2.0	74
	Water		BDL		

BDL = below detection limit
Total volume of Sample 24.1A water = 16.7 L. Total volume of Sample 24.1B water = 13.4 L.



Note: Percentages show mass distribution by size fraction.

Figure 10
Cesium-137 Distribution in CSX Soil

the feed material and the concentrations found in each soil fraction after treatment. The data show that the treated fractions larger than 75 µm are below the release criteria of 50 pCi/g of cesium-137. A mass reduction of approximately 70 percent was achieved (Figure 11), including the oversized material that was not decontaminated. The gross oversized material (larger than 2 in.) accounted for only 2 percent of the mass. A mass balance performed over the entire system shows a mass accountability of 96 percent. The raw data from this test are included in Appendix C.

The water used in the system was collected and analyzed for cesium-137. The data showed that the cesium-137 was not soluble in water and that the water met the criteria for acceptance by the Central Neutralization Facility (wastewater treatment facility) at K-25.

9.0 COST ANALYSIS

Costs were tracked throughout the various runs of the VORCE machine to obtain data for predicting costs for a full-scale process unit. To get a representative determination of the costs associated only with processing, costs were evaluated for the time period during which the Maywood soils were processed. These costs are summarized in Table 4. The cost data for the VORCE (shown in column 1) were based on one week in which approximately 20 tons of Maywood soil was processed. The data include costs for shipment, disposal, transportation, preparations for shipping the material to Envirocare, LMES support, rental of generator and diesel power equipment, and related labor. Site preparation costs are not included in the total but are presented for informational purposes. Many of the support requirements (i.e., Lockheed Martin, technical analysis) could be eliminated during a full-scale run. Much of the additional support was associated with test and evaluation of properties of soil treatment prior to disposal, operations not required during a full-scale remedial action.

Columns 2 and 3 of Table 4 show the estimated cost for operating a 20-ton/hr machine based on remediating 50,000 yd^3 (65,000 tons) of contaminated soil and a 100-ton/hr machine remediating 100,000 yd^3 (130,000 tons). Full-scale machines such as these could be operated with the same personnel as the VORCE operated at 0.5 ton/hr, providing 40 or 200 times the throughput for the same time period. The bases for the full-scale treatment estimate are as follows:

- Soil has been excavated and is stored onsite. Excavation costs are not reflected.
- The soil properties are similar to those in the Maywood pile (i.e., contaminants are attached to fine silts/clays, approximately 30 percent fines). Large variations in these conditions will affect cost and are therefore not reflected here.
- The labor rate is assumed to be the average Davis-Bacon rate for DOE projects.

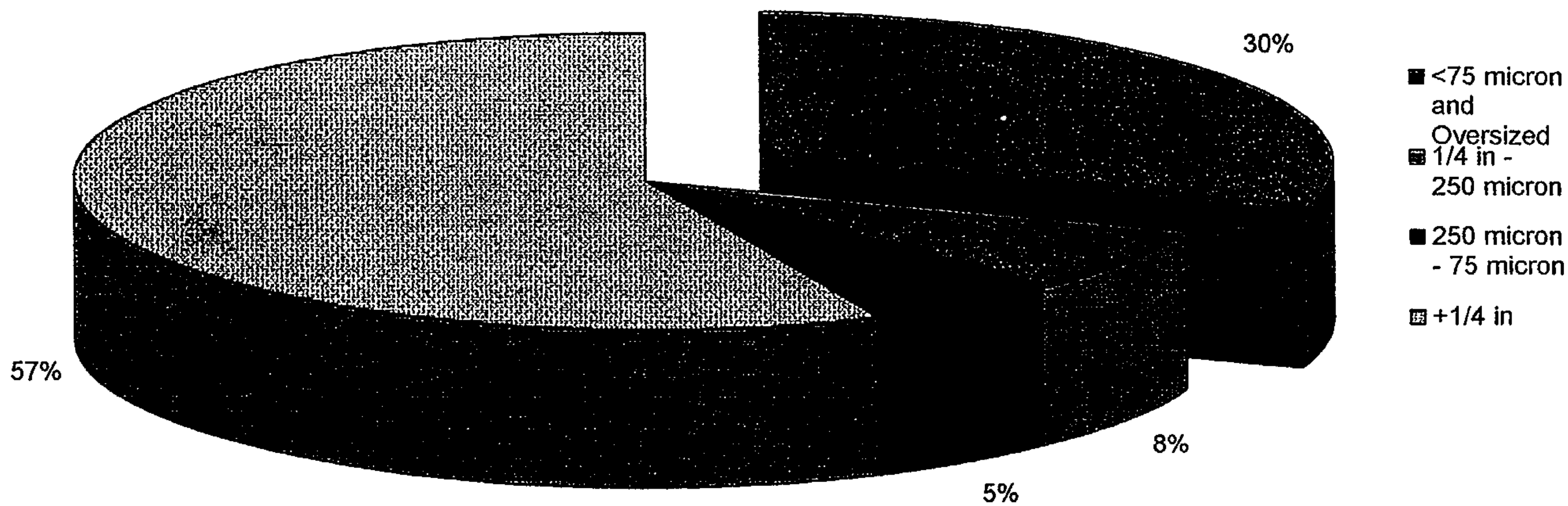


Figure 11
Particle Distribution by Mass in CSX Soil

Table 4

Cost Comparison Between VORCE and a Full-Scale Plant

Item	VORCE	20 ton/hr Full-scale	100 ton/hr Full-scale
Utilities	$548	$222,950	$445,900
Equipment rental	$6,385	$251,000	$313,386
Labor	$8,800	$1,060,200	$441,750
Health physics technician	$4,400	$216,000	$90,000
Sample analysis	$8,456	$78,000	$30,000
Geological support	$6,600	$0	$0
Waste management support	$17,050	$0	$0
Consumables	$2,147	$155,256	$65,000
Transportation of soil to treatment facility	$26,050	$0	$0
Mobilization/Demobilization/ Equipment	$0	$150,000	$200,000
Shipping/disposal wastes	$19,250	$4,702,800	$9,795,600
Soil preparation for disposal	$22,000	$20,000	$40,000
K-25 support	$32,898	$0	$0
Site preparation	[$186,000][a]	$90,000	$90,000
Subtotal	$154,584	$6,946,206	$11,511,636
Total including 25% Contingency		$8,682,758	$14,389,545
Cost per ton (treatment with disposal)	$7,729	$134	$111
Cost per ton (treatment without disposal)		$43	$17

[a] Not included in the subtotal

- A health and safety representative is assigned to the project.
- Treated clean soil will be disposed of onsite.
- Treated contaminated soil will be transported by rail to Envirocare for disposal (transportation and disposal costs $313.52/yd^3$).
- Soil density of 1.3 tons/yd^3.
- Online percentage of 90 percent (20 hr/day) using a 20-ton/hr machine.
- Permit requirements are minimal.
- Three samples will be collected per week for the duration of the project.
- National Pollutant Discharge Elimination System (NPDES) permit exists at the site, allowing process water to be disposed of at a publicly owned treatment works at project completion.
- Power will be supplied by a source at the site. No generator will be required.
- The site water supply will be used for the system.
- Mobilization and erection will require two weeks. Dismantlement and demobilization will also require two weeks.
- Extra equipment will include a fork truck, trailer, etc.
- Power and water rates are based on costs reported in Bergmann USA Soil Sediment Washing Technology Applications Analysis Report (EPA 1995).
- Mobilization costs are based on Bergmann USA information (EPA 1995) assuming 1,000 miles mobilization/demobilization distance.
- Costs for the 20-ton/hr unit (50,000 yd^3) are based on 6-month treatment time, 7-month total project.
- Costs for the 100-ton/hr unit (100,000 yd^3) are based on 2.5-month treatment time, 4-month tota project.

- Consumable rate (disposable protective personal equipment, polymer, etc.) is scaled up from the VORCE costs over time.

- Excavation is required no matter the fate of the waste; therefore, this cost is not included in the cost comparison. It is estimated that excavation will add approximately $20/ton to the overall cost.

- Labor consists of three operators, one supervisor, one half-time maintenance technician, one half-time health and safety representative, and one full-time health physics technician per shift.

- Waste management and transportation support will be provided on a part-time basis.

As with the pilot demonstration, one of the major costs of the operation would be final transportation and disposal of the processed soil. Given all the above factors and a 25 percent contingency, it is estimated that it would cost $134/ton at 20 tons/hr or $111/ton at 100 tons/hr for treating similar soils. Comparable cost for "hog and haul" disposal for the site is $365/yd^3 ($280/ton).

10.0 SUMMARY AND CONCLUSIONS

The objectives of the VORCE pilot test were met, as summarized below:

1. Laboratory studies indicate that mass reduction of 65 to 70 percent is possible. Determine whether the soil washing process can track within 90 percent or greater of this process (i.e., 59 to 63 percent mass reduction) and whether the clean streams have thorium-232 concentrations below 5 pCi/g.

   Processing of the Maywood soil achieved 63.8 percent mass reduction determined by the laboratory tests. The test also succeeded in meeting the cleanup criteria for fractions greater than 75 μm. The CSX soils were also found to be amenable to treatment by soil washing. A letter report on this subject is included as Appendix C.

2. Identify health and safety issues associated with plant operation with regard to workers and the local community.

   The site and workers were monitored during operation of the plant. Air sampling and monitoring of sound levels indicated that these parameters were below compliance criteria, and no excess noise or fugitive dusts or emissions were generated by the machine.

3. Determine whether operation of the plant has any additional potential impacts on workers and the community or requires extraordinary measures to protect the workers and the community.

   Several operational issues were identified with regard to running the system in cold weather. If the ambient air temperature is below freezing, the polymer lines and the seal water in the pumps have the potential to freeze and damage those systems, which may preclude winter operations. Dust was not a problem with soil from the Maywood pile; therefore, it was not necessary to wet the soil before it was fed into the soil washing machine. Sound levels within 10 ft of the machine were below hearing protection limits; at 200 ft, levels decreased to background. Data indicate that no additional precautions are necessary to protect the community.

4. Estimate cleanup costs using a full-scale soil washing plant that uses only particle size separation technology for comparison with other options.

   The estimated cost for a full-scale plant ranges from $111/ton to $134/ton, depending on system size and amount of soil treated.. The comparable cost for excavation, transportation, and disposal is $365/yd^3 ($280/ton). Although actual costs for this study were burdened by excessive transportation and operating expenses, projected costs for full-scale plant operation are more competitive.

5. Evaluate the potential for the waste to be classified as either a hazardous waste as defined by RCRA or a mixed waste.

   The fine stream (less than 75 µm) was the stream most likely to become a mixed waste. Sampling of the fine stream (greater than 75 µm) was conducted because this stream would be the most concentrated. Analytical results for this stream indicated that the TCLP levels for the metals were below regulatory concern.

6. Debug the system and obtain operating experience.

   The team operated the system for a total of 766.5 hours using clean and radioactively contaminated soil. During this time, the team was able to solve the operational problems encountered.

7. Evaluate the performance of individual unit operations and optimize the system.

   The operations were evaluated; Table 1 shows some of the operational settings used. The process is dependent on the particle size desired and the type of material processed. The setting must be adjusted for each type of material. The unit processes operated within their effective efficiency ranges in the coarse circuit. Improper feed pump size affected the efficiency to produce a cut finer than 75 µm.

8. Recommend process modifications to improve full-scale performance.

The studies indicated that performance would be improved by replacing the existing hydrocyclone feed pump by a more powerful unit. The current pump cannot provide the appropriate feed rate to ensure that the hydrocyclone operates properly, therefore limiting the ability of the unit to make a 325 mesh (45 μm) cut.

9. Provide stakeholders an opportunity to observe the system on a pilot scale.

A representative of Maywood Environmental/Legislative Action Committee (ELAC) visited the soil washing operation and reported his findings to the committee.

11.0 REFERENCES

U.S. Environmental Protection Agency (EPA), *Bergmann USA Soil Sediment Washing Technology Applications Analysis Report*, EPA/540/AR-92/075, September 1995.

EPA, *Characterization of Soil Samples from the Maywood Chemical Company Site*, National Air and Radiation Environmental Laboratory, March 17, 1993.

U.S. Bureau of Mines, *Conceptual Design and Economic Analysis of a Process to Treat Radiation-Contaminated Soils at Maywood, New Jersey*, A. R. Rule, D. C. Dahlin, and J. J. Henn, March 7, 1994.