Case Study Abstract

Cost Report: Windrow Composting to Treat Explosives-Contaminated Soils at Umatilla Army Depot Activity (UMDA)

Site Name:
Umatilla Army Depot Activity (UMDA)

Location:
Hermiston, Oregon

Contaminants:
Explosives
- Primary soil contaminants include 2,4,6-Trinitrotoluene (TNT); Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); and 2,4,6-Trinitrophenylmethylnitramine (Tetryl)
- TNT and RDX soil concentrations ranged from 100 to 2,000 ppm; and HMX from <1 to 100 ppm
- Contamination present in top 6 ft of soil

Period of Operation:
March 1994 - September 1996 (anticipated end date)

Cleanup Type:
Full-scale remediation

Vendor:
Wilder Construction Co. (Phase I)
Bioremediation Services, Inc. (Phase II)

SIC Code:
9711 (National Security)

Technology:
Composting (Windrow)
- Soil excavated and stored on site (Phase I)
- Soil treated inside 200 x 90 ft structure (Phase II)
- Moisture content maintained at 30-35%
- Turning frequency was once every 24 hrs for first 5 days followed by less frequent turning on subsequent days
- Composting batches required approximately 22 days to reach cleanup goals
- Full-scale treatment based on 3 trial tests

Cleanup Authority:
CERCLA
- ROD Date: September 1992

Point of Contact:
Remedial Project Manager
Umatilla Army Depot Activity
Hermiston, OR

Waste Source:
Surface Impoundment/Lagoon

Purpose/Significance of Application:
First full-scale application of windrow composting to biodegrade explosives-contaminated soils

Type/Quantity of Media Treated:
Soil
- 10,969 cubic yards (13 windrows with 810 cubic yards each and 1 windrow with 439 cubic yards)
- Predominantly Quincy fine sand and Quincy loamy fine sand
- Soil pH gradually increased from 7 (at ground surface) to 8.5 at 5 ft below ground surface

Regulatory Requirements/Cleanup Goals:
- Concentrations of explosives in soil of less than 30 ppm for each of target compounds - TNT and RDX

Results:
- Windrow composting generally reduced the levels of target explosives to below the cleanup goals
- Average concentrations prior to composting were 190 ppm for TNT and 227 ppm for RDX
- 27 x 30 cu. yd. grids sampled in each batch
- Through 11 batches, only 2 of almost 300 grids did not meet cleanup goal after initial phase of treatment

Cost Report: Windrow Composting to Treat Explosives-Contaminated Soils at Umatilla Army Depot Activity (UMDA) (Continued)

Cost Factors:
- Actual total project cost of $5,131,106, corresponding to a unit cost of $346 per ton from mobilization to demobilization
- Phase I cost $1,320,162 (soil excavation and storage)
- Phase II cost $3,810,944 (soil treatment)
- Costs specific to biological treatment ($1,989,454) correspond to unit cost of $181/cubic yard soil treated

Description:
From approximately 1955 to 1965, the UMDA operated a munitions washout facility in Hermiston, Oregon, where hot water and steam were used to remove explosives from munitions casings. About 85 million gallons of heavily-contaminated wash water were discharged to two settling lagoons at the site. The underlying soils and groundwater were determined to be contaminated with explosive compounds, primarily TNT, RDX, and HMX, and the site was placed on the NPL in 1987.

Windrow composting was used for a full-scale remediation at UMDA, with treatment taking place from July 1995 to September 1996 (anticipated completion date per September 1996 report). A total of 10,969 yd^3 of contaminated soil were treated at UMDA, in 14 batches. Analytical results indicated that average concentrations were reduced from 190 to <30 ppm for TNT, and from 227 to <30 ppm for RDX. Through 11 batches, only two of almost 300 grids did not meet the cleanup goal (30 ppm) after an initial phase of treatment.

Detailed information on actual costs for this application are provided in the report. Actual costs are shown according to an interagency Remedial Action-Work Breakdown Structure (RA-WBS). Factors affecting costs that were identified for this application included climate, soil characteristics, and amendment availability and cost. For example, the semi-arid cool climate and sparse vegetation at UMDA contributed to fairly low preparatory site work cost. Amendment availability and cost are significant factors for composting and are driven by the proximity, seasonality, quality, and consistency of the materials to be used. At UMDA, the majority of the amendments were readily available in the Umatilla area.

Executive Summary

This report documents the cost for the first full-scale use of windrow composting to remediate explosives-contaminated soils. The results of this cost report will allow managers of other sites with explosives-contaminated soils to estimate the cost of remediation using the windrow composting technology, assuming similar site-specific variables. Estimates for sites with different site conditions (e.g., nature and extent of contamination, soil type, climate) and remedial action goal must scale subelement costs according to individual site characteristics.

The 1992 Remedial Investigation and Feasibility Study (RI/FS) for the Umatilla Army Depot Activity (UMDA), located in Hermiston, Oregon, concluded that although both incineration and composting constitute technically effective remediation methods for reducing explosives concentrations in soils, windrow composting appears to be more cost-effective based on preliminary trial tests and small-scale demonstration data (9). As a result, the 1992 Record of Decision selected windrow composting to remediate contaminated soils from two munitions washout lagoons at UMDA.

The remediation effort at UMDA was performed in two phases by two separate contractors. Phase I work included excavation of the contaminated soils from the lagoons, erection of a soil storage building, and stockpiling of the excavated soil in the storage building. Phase II work included preparation of three trial tests to determine the optimal amendments mixture, full-scale production composting, demobilization, and site restoration. The total volume of soil excavated and subsequently remediated was 10,969 cubic yards. This total soil volume is an increase of 40 percent over the original estimated 6,339 cubic yards.

This cost report concludes that windrow composting costs $346 per ton of contaminated soil at UMDA. This unit cost is based on all costs associated with Phase I and Phase II and does not include U.S. Army Corps of Engineers (USACE) cost for support and contracts. Explosives concentrations were as high as 88,000 parts per million (ppm) for TNT and 1,900 ppm for RDX before treatment. The 1992 Record of Decision, which presents the selected remedial action, specifies the cleanup goal of <30 ppm each for TNT and RDX. Both TNT and RDX achieved explosives reduction after treatment to below the 30 ppm cleanup limit.

This report presents cost data using the Remedial Action-Work Breakdown Structure (RA-WBS), the standard cost methodology for remediation work accepted by the Federal Remediation Technologies Roundtable, which includes the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Department of the Interior, and the U.S. Department of Defense. The three largest cost elements for the remediation project at UMDA, in order, are:

Table ES-1. Summary of Largest Cost Elements

WBS Item	Activity	% of Total Phase I and Phase II Cost
33.11	Biological Treatment	39%
33.01	Mobilization and Preparatory Work	25%
33.03	Site Work	10%

The USACE cost for support (engineering, supervision, administration) and contracts (Invitation for Bid and Request for Proposal) was also significant at 21 percent of total project cost (Phase I plus Phase II plus USACE cost). The USACE cost for support and contracts represents a fixed cost; that is, this cost is independent of project duration or volume of contaminated soil to be treated. Mobilization & Preparatory Work and Site Work (e.g., clearing and grubbing) also represent fixed costs at UMDA because the costs do not vary with soil volume. Although Site Work is a fixed cost at UMDA, this cost will vary at other sites given different site conditions (e.g., vegetation, site area, topography). Biological Treatment, however, is a variable cost because its subelement costs will vary according to site specific conditions (e.g., nature and extent of contamination, soil type, climate, regional labor rates, amendments availability) and the remediation goal (e.g., extent of explosives reduction, volume of contaminated soil).

1.0 Introduction

1.1 Purpose

The purpose of this report is to present the cost data for the first full-scale use of windrow composting to treat explosives-contaminated soils at the Umatilla Army Depot Activity (UMDA) in Hermiston, Oregon. The results of this report will allow managers of other explosives-contaminated sites to evaluate the cost benefits of using windrow composting and estimate the cost for remediation using this technology for treatment. Although preliminary economic analyses and pilot scale demonstrations of windrow composting have been completed to indicate cost savings and explosives reduction, this report documents actual field cost data from a full-scale remediation effort. Cost data are presented using the Remedial Action Work Breakdown Structure (RA-WBS), a standard cost methodology for remediation work accepted by the Federal Remediation Technologies Roundtable, which includes the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Department of Interior, and the U.S. Department of Defense. The RA-WBS identifies project-specific cost elements (either fixed or variable, defined in section 4.2.1) that can be scaled to estimate costs at other sites considering the use of windrow composting to remediate explosives-contaminated soil. In addition to documenting cost, this report offers some recommendations to optimize overall cost at other sites.

1.2 Scope

This report documents the costs associated with the first full-scale use of windrow composting to treat explosives-contaminated soils at UMDA. The UMDA Record of Decision directed the U.S. Army Corps of Engineers (USACE) to apply windrow composting to remediate the explosives-contaminated soils from two washout lagoons at UMDA. Cost data presented in this report were provided by the USACE contractors performing the excavation and remediation.

This report does not include a comparative evaluation of this innovative technology against other treatment methods, including incineration, but it is important to note the unit cost of incineration in order to confirm the cost effectiveness of windrow composting. Historically, incineration has been the selected method of treatment, effective in destroying 99.99 percent of explosive contaminants (9). However, incineration is costly at $740 per ton for treating less than 10,000 tons of soil (4). The unit cost of incineration decreases with increased soil volume to be treated due to high up-front capital costs. Preliminary studies for windrow composting show that it can be 97 to 99 percent effective in destroying explosive contaminants and be cost-effective at an estimated $326 per ton for 10,000 tons of contaminated soil over a project duration of 2 years (8). This report uses actual cost data to identify unit cost (dollars per ton of contaminated soil).

2.0 Background Information

A Remedial Investigation and Feasibility Study (RI/FS) was prepared in 1992 by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center (USAEC), to evaluate alternative methods for remediating explosives-contaminated soils at UMDA. This initiative was undertaken in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986, commonly referred to as Superfund, to gather information and initiate the cleanup process. The RI/FS concluded that although both incineration and composting are effective methods for reducing explosive concentrations in the contaminated soils to acceptable levels, composting using a windrow system is more cost-effective than incineration for the situation at UMDA. A September 1992 Record of Decision (ROD) selected windrow composting to remediate the contaminated soils from two washout lagoons at UMDA.

2.1 Site History

UMDA was established in 1941 as an Army ordnance depot to store and handle munitions. UMDA operated an onsite explosives washout plant from the 1950s until 1965. The plant processed munitions to remove and recover explosives using a pressurized hot water system. Water used in the washout process was recycled during plant operation, and the washout system was flushed and drained weekly. The spent washwater was then discharged into two adjacent infiltration/evaporation lagoons, an acceptable industrial practice at that time. An estimated 85 million gallons of effluent were discharged into the lagoons during the period of plant operation. Residual explosives contained in the washwater were later found to have contaminated the soil and groundwater under the lagoons. The lagoons were placed on the National Priorities List (NPL) in 1987.

2.1.1 Site Description

UMDA occupies nearly 20,000 acres of land and straddles Umatilla and Morrow counties in northeastern Oregon (Figure 2-1). The contaminated lagoons, designated the north and south lagoons, are located in a depression in the central part of UMDA (Figure 2-2) and are rectangular in shape. The north lagoon measures 51 feet by 98 feet at the top and 39 feet by 80 feet at the bottom. The south lagoon measures 42 feet by 98 feet at the top and 27 feet by 80 feet at the bottom. All measurements are approximate. The sides are sloped approximately 35 degrees. Both lagoons are approximately 6 feet deep, with sandy bottoms and gravel sides. A gravel berm 15 feet wide separates the lagoons. (See Figure 2-3 for dimensions of the lagoons.)

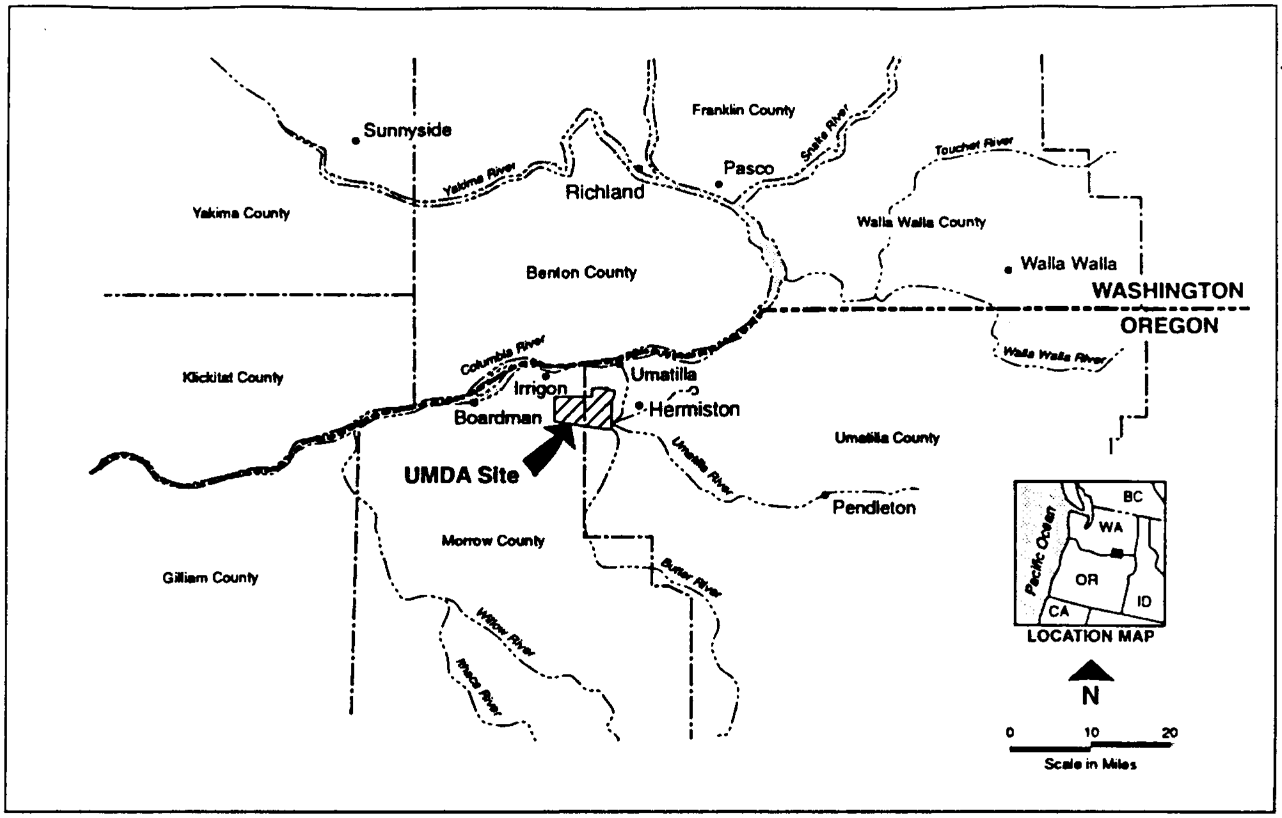

Figure 2-1. Facility Location Map, UMDA

Source: (9)

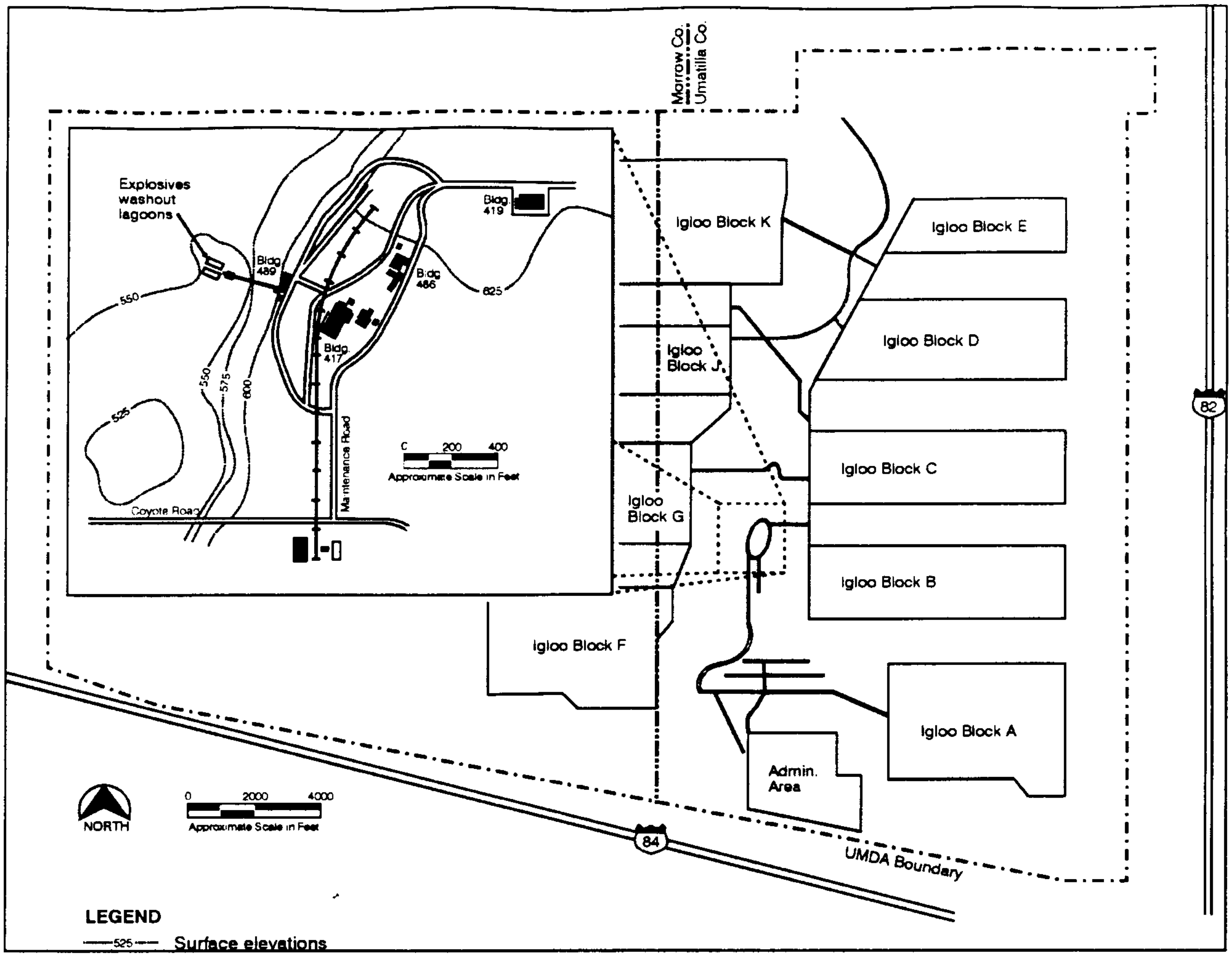

Figure 2-2. Location of Explosives Washout Lagoons, UMDA

Source: (9)

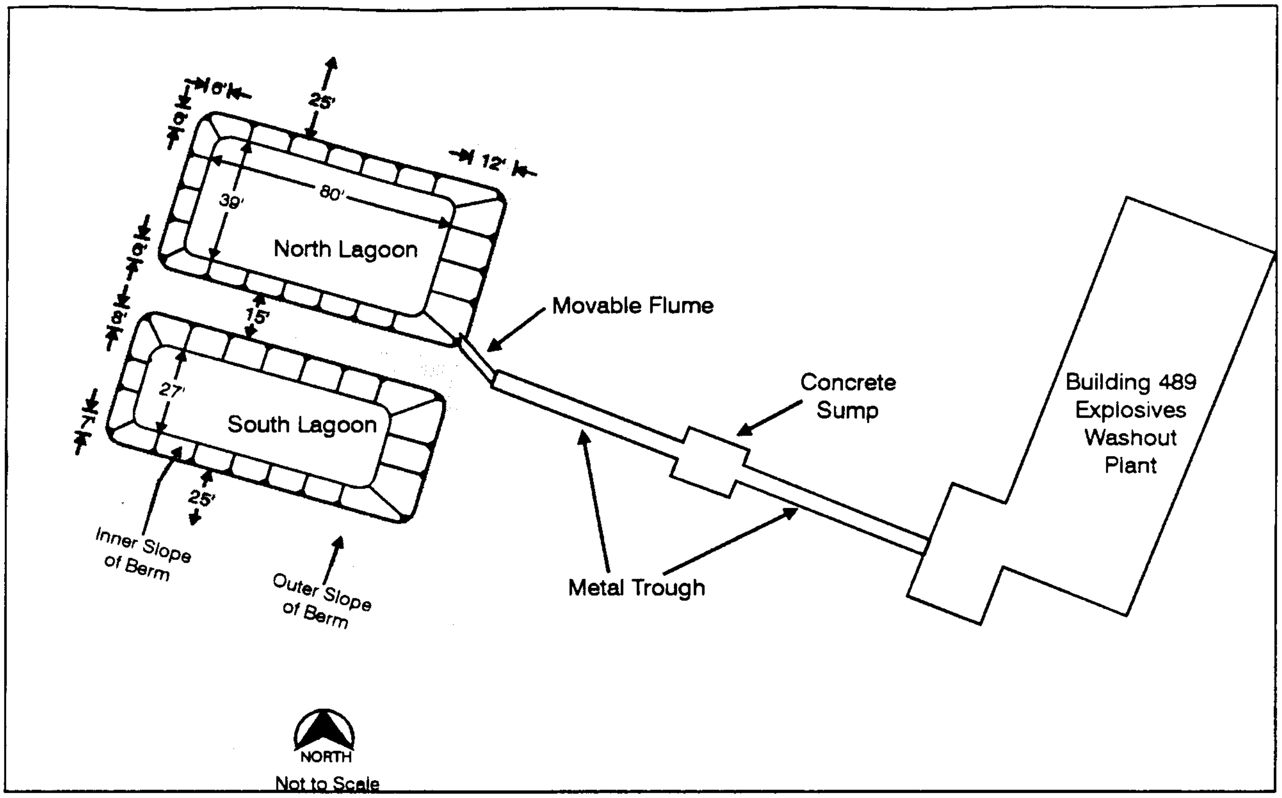

Figure 2-3. Explosives Washout Lagoons and Washout Plant Area, UMDA

Source: (9)

The remainder of this section provides site-specific information on the climatology, soils, surface hydrology, and geology and hydrogeology at UMDA. This information is important in establishing the environmental conditions at UMDA, which will in various degrees affect the determination of cost at other regions.

Climatology

The area is characterized by a semi-arid, cold desert climate (9). Average annual precipitation is 8 to 9 inches, with rainfall occurring mostly between November and March. The evapotranspiration rate is high, at 32 inches per year. Average temperature at UMDA is 75°F during the summer and 35°F during the winter. Wind data, routinely collected at the Pendleton Municipal Airport, located 30 miles east of the UMDA facility, indicate mean wind speed of 8 to 11 miles per hour with prevailing west and southwest winds.

Soils

The soils surrounding the lagoons are predominantly Quincy fine sand and Quincy loamy fine sand. Quincy fine sand is a very deep, excessively drained soil formed in mixed sand. Soil permeability is high, and water-holding capacity is low. Soil pH gradually increases with depth from about 7 (neutral) to 8.5 (basic) at 5 feet below the ground surface (9). Vegetation is scarce around the lagoons, increasing the risk of wind erosion. Soil organic matter is generally less than 0.5 percent. Quincy loamy fine sand exhibits similar characteristics. Found on slightly flatter slopes, it has slightly more silt and clay in the upper layer, resulting in a higher water holding capacity than Quincy fine sand.

Surface Hydrology

There are no perennial streams within the UMDA facility because of the high permeable nature of the soils. Runoff is diverted away from the lagoons by the raised berms, and any water collected in the lagoons infiltrates very quickly. Surrounding rivers include the Columbia River, located approximately 3 miles north of the northern boundary of UMDA, and the Umatilla River, located approximately 1 to 2 miles east of UMDA (9).

Geology and Hydrogeology

The geology at UMDA is characterized by three distinct geological units: unconsolidated glacial flood gravels (alluvium), which range in thickness from 50 feet to 154 feet in areas surrounding the lagoons, based on topographic variation; cemented basalt gravel/weathered basalt, ranging in thickness from 14 feet to 28 feet, with underlying gravels 30 to 50 feet thick; and basalt, which ranges in thickness of 89 feet to 106 feet (9).

The depth to groundwater varies seasonally, from 44 feet to 49 feet below the bottom of the lagoons. Groundwater flows predominantly towards the northwest. Groundwater well sampling indicate low levels of explosives contamination from the lagoons. Groundwater treatment is being evaluated separately (9).

2.1.2 Contaminants of Concern

The principal explosives from the munitions were—

- 2,4,6-Trinitrotoluene (TNT);
- Hexahydro-1,3,5-trinitro-1,3,5-triazine (commonly referred to as Royal Demolition Explosive or RDX);
- Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (commonly referred to as High Melting Explosive or HMX); and
- 2,4,6-Trinitrophenylmethylnitramine (Tetryl).

The munitions also contained 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), trinitrobenzene (TNB), dinitrobenzene (DNB), and nitrobenzene (NB), occurring as either impurities or degradation products of TNT.

Contamination by TNT, RDX, HMX, TNB, and 2,4-DNT were most frequently detected in the soil. TNT and RDX concentrations were highest, typically ranging from 100 to 2,000 parts per million (ppm) to a depth of 3.5 feet and generally less than the cleanup level of <30 ppm below 3.5 feet. The maximum concentration of TNT was detected in the top inch of soil at 88,000 ppm. HMX concentrations ranged from below detection (<1 ppm) to 100 ppm at a depth of 4 to 6 feet. TNB concentrations ranged from 2 ppm to 47 ppm, while 2,4-DNT concentrations were low (below detection [<1 ppm] to 5 ppm). Tetryl, 2,6-DNT, DNB, and NB were rarely if ever detected, and then only at low (<5 ppm) concentrations.

The 1992 ROD which presented the selected remedial action, in accordance with CERCLA, for the Explosive Washout Lagoons Soils at UMDA specifies the reduction of TNT and RDX concentrations of 30 ppm or less for each contaminant. Because of the much lower concentrations and total quantities of the other contaminants, they were not considered in establishing remedial goals. Previous studies have also shown that reduction of TNT and RDX indicate a commensurate reduction of other explosives to levels which would pose no significant risk to human health and the environment.

2.2 Technology Description

Composting is a natural process in which microorganisms biologically degrade organic materials under controlled conditions. The main advantage of composting, as compared to incineration, is cost. Composting also minimizes the risk of releasing hazardous products into the atmosphere. Both of these attributes make it a more acceptable remediation approach to public stakeholders. Composting has been performed for many years for the treatment of municipal waste and wastewater sludges, but its application to explosives-contaminated soils is innovative.

Composting is initiated by mixing biodegradable organic matter with bulking agents and other amendments. Bulking agents (e.g., sawdust, wood shavings) enhance the porosity of the mixture to be composted while amendments, such as agricultural and animal waste, provide nutrients to sustain microbial growth. The use of bulking agents can significantly increase the final volume of targeted material, which may have an impact on its redistribution at the site if space is limited. Composting usually occurs under aerobic (with oxygen), thermophilic (temperatures ranging from 55°C to 60°C) conditions. Other control parameters (besides oxygen content and temperature) are moisture content, compost pH, type and concentration of organic constituents, and concentration of inorganic nutrients (e.g., nitrogen and phosphorus).

In composting using a windrow system, the soil and amendment mixture are formed into elongated piles (windrows) on an impervious surface and turned periodically. Windrows are typically 4 to 6 feet high and 10 to 12 feet wide, with length of the windrow determined by the size constraints of the pad surface or work area. The windrow piles are mechanically turned on a regular basis to aerate the mixture, distribute heat and moisture, and ensure even composting. The next chapter (Chapter 3) details the application of windrow composting at UMDA.

2.3 Project Description

The remediation project, supported by USACE, was conducted in two phases. The phased procurement approach employed at UMDA came about, in part, because of a requirement imposed by CERCLA which stipulates that physical onsite remedial action must begin within 15 months of the issuance of the ROD which was signed in September 1992. Pressed with the possibility of receiving a Notice of Violation (NOV) and other penalties if the deadline was not met, the USACE opted to divide the project into two phases. Phase I would cover the routine excavation and construction portion and be offered in the faster Invitation for Bid (IFB) solicitation format while Phase II, which would cover the entire remediation process, would be offered using the more lengthy Request for Proposal (RFP) solicitation process. By dividing the remediation work effort, USACE was successfully able to prepare and award the IFB for Phase I prior to the deadline, thereby effectively negating any associated violation or penalty. However, this contracting strategy also introduced some duplication of effort (and therefore, costs), given that two contracts now existed where only one had originally been envisioned.

Phase I, which has been completed, was performed by Wilder Construction Company and included the excavation of the soils from the lagoons, erection of a soil storage building, and stockpiling of the excavated soils in the storage building. Phase II, which is currently under way, is being performed by Bioremediation Services Incorporated. This portion of the project included the preparation of three trial tests to determine optimization of amendment mixture, equipment and operating procedures; full-scale production composting; demobilization; and site restoration. Details of the project, by Phase, are provided in Chapter 3. Events are presented in chronological order to establish a reference to time of year and length of activity.

3.0 Remediation Process

3.1 Phase I

Analytical results from composite borehole samples taken around the lagoons were used to estimate an approximate volume of 6,339 cubic yards (cy) of contaminated soil. A Contaminated Soil Storage Building (CSSB) was built to accommodate this soil volume for storage and subsequent treatment in Phase II. Post excavation survey of the lagoons revealed thin seams of soil contamination extending beyond the initially excavated area. The Phase I contractor, Wilder Construction Company (WCC), then excavated the additional soil, which was placed in the remaining areas (designated for later use as the treatment area) of the CSSB and on an adjacent asphalt pad, with a reinforced polyethylene liner for cover. The total volume of soil excavated by WCC was 13,245 cy (10,845 cy of contaminated soil plus 2,400 cy of clean soil), an increase of 50 percent over the estimated volume. This increase in volume triggered a chain of events that significantly affected the cost of the remediation and is discussed in subsequent sections as well as in the summary of costs in Chapter 4.

3.1.1 Planning and Contracting

After extensive planning, design, and contract preparation on the part of the USACE, the IFB for Phase I was released, and WCC successfully responded. Initial activity under the contract included the preparation and submission of a number of preconstruction submittals and implementation plans. After receiving a Notice to Proceed (NTP) on November 24, 1993, WCC prepared and submitted the Remedial Action Management Plan (RAMP), which consisted of the following components: Work Plan; Site Safety and Health Plan (SSHP); Contractor Quality Control Management Plan; Environmental Protection Plan; Spill Prevention Plan; Control and Countermeasures Plan; Security and Access Control Plan; Hazard Analysis; WCC Safety Program and Field Supervisor's Safety and Health Manual; Letters of Authorization and Appointment; Resumes and Certifications; Equipment Specifications; and Construction Layout Plans.

3.1.2 Site Setup

As the RAMP was undergoing review, the demarcation of the work zones, as provided in the SSHP, took place. These controlled zones included an Exclusion Zone (EZ), where contamination does or could occur; a Contamination Reduction Zone (CRZ), where decontamination will occur; and a Support Zone (SZ), which is a clean zone outside the CRZ. Only after being clearly delineated with colored tapes, fences, rope, and other barricades could site work commence.

After establishment of the controlled zones on March 14, 1994, the mobilization of construction equipment, facilities, and personnel took place in preparation for site setup work. Initial activities onsite included the clearing and grubbing of work areas, construction/upgrade of roads and decontamination pads to include sumps for wastewater collection/reuse during composting, establishment of temporary support facilities, hookup of temporary utilities, and construction of an asphalt pad for use in and around the storage building. An existing pad at the site, which was intended to be used, had to be replaced because its slope was too steep. This pad replacement necessitated a contract modification.

With concrete footings in place and foundation ready, assembly of a 200-foot by 90-foot prefabricated metal building known as the CSSB was completed on June 16, 1994 (Figure 3-1). This building was designed to accommodate storage of the initial estimated volume of approximately 6,400 cy of soil and subsequent processing activities. The CSSB prevented runoff and wind erosion of the contaminated soil in Phase I and was intended to accommodate composting operations during Phase II. Immediately adjacent to the CSSB, additional pad space was dedicated to the Material Process Area (MPA), where material stockpiling, processing, and drum handling would occur. In addition, ecology blocks (interlocking concrete blocks used to form retaining or barrier walls) were placed around the inside perimeter of the building (Figure 3-1) to contain and separate contaminated soil stockpiles. The SSHP required air monitoring (Figure 3-2) and dust and vapor control systems in the CSSB to ensure minimum air quality and safe working conditions. To provide ventilation and adequate air flow, 16 louvered exhaust fans were also installed in the CSSB (Figure 3-3).

Figure 3-1. Empty CSSB, UMDA

Figure 3-2. Treatment Building Real-Time Air Quality Monitoring, UMDA
MSA Model 260—Combination methane and oxygen monitoring station equipped with audio and visual alarms to notify personnel in the event preset safety levels are exceeded.

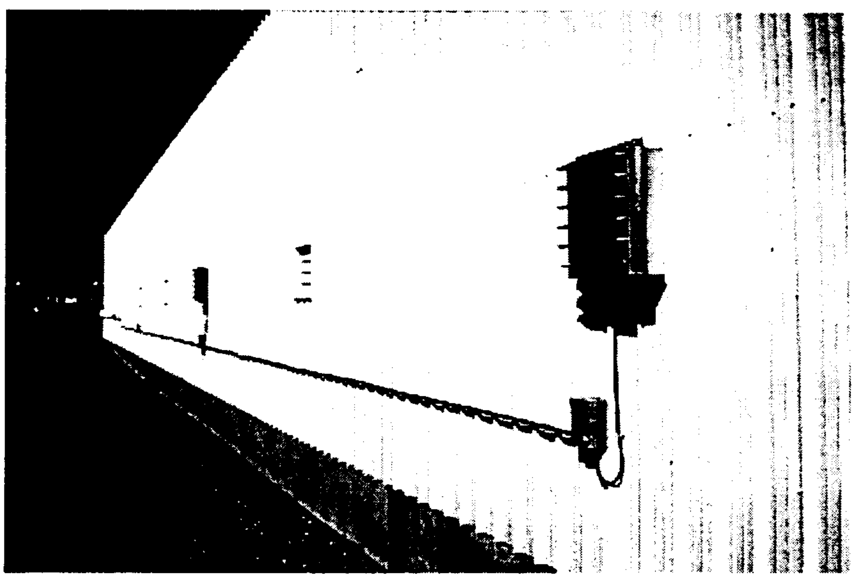

Figure 3-3. Powered Ventilation Fans, UMDA

Immediately after the CSSB was completed, WCC also decontaminated and removed the steel overflow trough, which allowed the spent rinsewater from the explosives washout plant (Bldg. 489 in Figure 2-3) to flow into the lagoons. The inlet and outlet ends of the concrete sump (refer to Figure 2-3), located at the base of the stationary portion of the trough, were sealed with non-shrink grout.

3.1.3 Excavation and Transport

With the soil storage building completed, work focused on the excavation of the contaminated soil from the lagoons (Figure 3-4), which continued from June 21 to July 11, 1994. The contaminated soil was transported via dump truck through a decontamination pad (concrete staging pad sloped to a sump for the collection of all contaminated runoff liquid upon pressure washing of vehicle undercarriage and wheels) to the MPA above the lagoons adjacent to the CSSB. WCC unloaded and screened the soil to remove rocks and debris in preparation for storage in the CSSB. Any non-contaminated soil that was excavated was stockpiled adjacent to the lagoons. Contamination of soil was verified by onsite analysis using EPA Method 8515 for TNT and Method 8510 for RDX. Personnel and perimeter air monitoring was performed during excavation and screening to ensure that airborne concentrations were below the maximum safe limits of 0.25 mg/m^3 for TNT and 2.5 mg/m^3 for respirable dust (Figure 3-5).

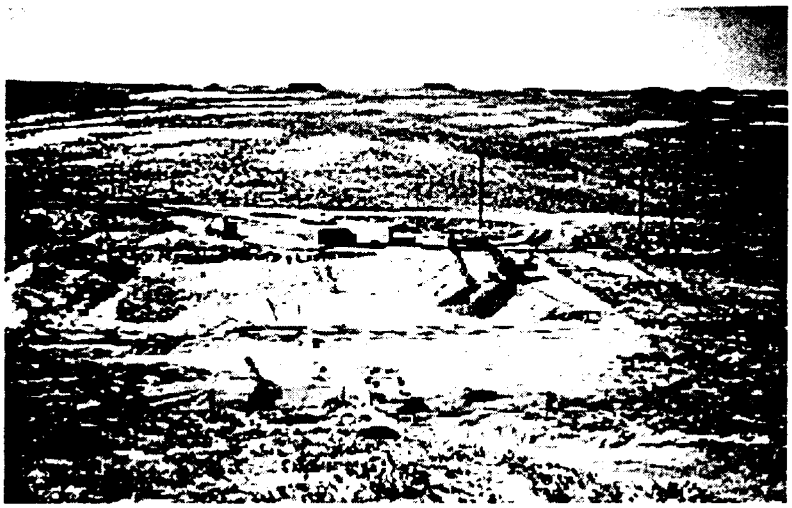

Figure 3-4. Lagoon Excavation, UMDA

Figure 3-5. Perimeter Air Monitoring, UMDA
Portable upwind/downwind integrated air sampler used to monitor respirable dust and airborne concentrations of TNT and RDX.

On July 11, 1994, WCC suspended excavation work because they were nearing maximum contract soil volume. This suspension occurred despite the appearance of a telltale reddish lens at the sides of the excavated area of both lagoons, indicating the residual presence of TNT. Efforts were temporarily redirected to the removal of storage drums from Buildings 411, 412, and 413 per contract modification. The storage drums were left over from previous RI/FS work at the site and contained either soil, water, or clothing. The drums containing soil were transported to the material handling area and screened in the same manner as the excavated soil; the drums containing water were set aside for inclusion in Phase II composting; and the drums containing clothing were shipped offsite for disposal.

WCC resumed excavation on July 25, 1994 after receiving a contract modification to excavate the additional volume of contaminated soil that did not achieve the <30 ppm cleanup level for TNT and RDX. Excavation under this contract modification was completed on August 1, 1994, with an additional day of soil screening required to screen the backlog of stockpiled soil. The contract modification also addressed the disposition of the soil contained in the drums. After sampling analysis for TNT or RDX indicated no levels >30 ppm, they were sealed and returned to Bldg. 412 pending decision on final disposition.

As reddish lenses of TNT-contaminated soil were still observed in the excavated lagoons, WCC returned, once again, to continue excavation of three stratified layers of contaminated soil in the four sidewalls of both lagoons. The three contaminated layers of soil were separated by non-contaminated soil. Excavation of both contaminated and non-contaminated soil from the sidewalls of the lagoons totaled 3,300 cubic yards. Another contract modification ($147,000) addressing the additional excavation, screening, sampling and analysis, and stockpiling was prepared to accommodate the total 10,845 cy of contaminated soil actually excavated.

Due to this unforeseen increase in soil volume, WCC was directed by USACE to store the excess contaminated soil outside the CSSB on the asphalt pad because the CSSB, which was designed and built to accommodate the original estimate of 6,339 cy, was at capacity prior to completion of soil excavation. Ecology blocks were used for containment and a reinforced 18-mil polyethylene liner was secured with sandbags for cover. This final excavation was completed on September 6, 1994.

3.1.4 Chemical Analysis

In accordance with the Contractor Quality Control Management Plan, rigorous onsite analyses for TNT and RDX within pre-established grids were performed using EPA Method 8515 for TNT and Method 8510 for RDX to guide excavation depths and widths where the cleanup level of <30 ppm had not yet been attained. Furthermore, composite samples were regularly taken, prepared, and shipped offsite to a chemical laboratory for confirmatory analysis using EPA Method 8330.

After the final excavation of the stratified layers, onsite analysis and confirmatory analysis of 40 discrete samples taken from 8 grids in the bottom of the lagoons indicated that cleanup criteria had been met for TNT but not for RDX. Further review of the analytical data by USACE indicated that the sampling and analytical process protocols had not been properly followed, prompting an additional 40 samples to be obtained and analyzed. This additional work triggered yet another contract modification and an extension of approximately 4 weeks to accommodate laboratory analysis. While the second sample batch was being analyzed (and ultimately accepted), WCC effected temporary closure of the lagoons by laying in approximately 2 feet of gravel and performing a final grading of the excavated area.

3.1.5 Decontamination, Demobilization, and Site Restoration

Decontamination, demobilization, and site restoration of Phase I activities began after excavation was completed. All equipment was decontaminated and inspected; utilities were cut off and removed; and all temporary and supporting facilities were either properly disposed of and/or removed from the site. Phase I closeout occurred on September 20, 1994. A timeline of Phase I activities is provided below in Table 3-1.

Table 3-1. Phase I—Timeline

Activity	Start Date	Finish Date
Notice to proceed	November 24, 1993	—
Site Setup	March 14, 1994	June 16, 1994
Excavation and Transport	June 21, 1994	September 6,1994
Chemical Analysis	June 21, 1994	September 14, 1994
Decontamination, Demobilization, and Site Restoration	September 14, 1994	September 20, 1994

3.2 Phase II

As mentioned in Section 2.3, some duplication of effort was inevitable because of the use of two contracts. Much of this duplication was evident in Phase II, beginning with the contract preparation on behalf of the USACE followed by Bioremediation Services Incorporated's (BSI) preparation of the first of two RAMPs for Phase II and the subsequent remobilization of the site. A second RAMP was required in Phase II to incorporate the results of the trial tests as well as the comments regarding RAMP I. Furthermore, the chain of events and added costs associated with the increased soil volume in Phase I were also apparent in Phase II.

3.2.1 Planning and Contracting

The contract for Phase II of the remediation effort was awarded to BSI upon completion of a protracted selection, evaluation, and award process. After receiving a NTP on June 13, 1994, BSI prepared the first RAMP containing the following subdocuments: Composting Treatment Trial Test Plan; Site Safety and Health Plan (SSHP); Contractor Quality Control Management Plan; Environmental Protection Plan; Ventilation Plan; Network Analysis Plan (Integrated Project Activity Duration Spreadsheet); and Temporary Treatment Building Plan. USACE issued approval of the Final RAMP I on November 18, 1994.

3.2.2 Site Setup

As BSI reestablished work zones per the SSHP, they also mobilized construction equipment, facilities, and personnel in preparation for site setup work. Initial site activity began on December 19, 1994, and included the following: grubbing and clearing of work areas, construction of roads and decontamination facilities, establishment of a field office, installation of an onsite laboratory, hookup of temporary utilities, and preparation of a baseline air monitoring survey.

The existence of the additional volume of excavated contaminated soil prompted USACE to exercise one of its contract options to lease temporary building storage space from BSI for the soil. BSI provided the space in the form of three tents (owned by BSI) erected adjacent to the CSSB. The tents provided for storage of all contaminated soils so that the CSSB could be emptied and used solely as the treatment facility. All soil, except the first batch of soil intended for treatment, would be moved from the CSSB and the adjacent asphalt pad into the BSI tents to provide adequate ventilated space for BSI's turning equipment in the treatment building.

The BSI tents were leased to USACE with a contract modification of $487,000, which includes the costs for a 2-year lease on the BSI tents, site setup of the tents, and demobilization of the tents. Site setup for the tents included clearing, grubbing, and grading in preparation for an asphalt pad on which the tents were placed. The tents provided 42,250 square feet of soil storage space to accommodate the storage of all excavated soil stored in the CSSB and on the nearby asphalt pad. The tents were delivered to the site on January 30, 1995, and were erected by February 9, 1995. The movement of all contaminated soil (including the soil stored in the CSSB and the soil stockpiled on the adjacent asphalt pad) into the tents was delayed because one of BSI's subcontractors was unable to ensure all employees had proper hazmat certifications. After this was rectified, the soil transfer process began on March 7, 1995, and concluded the following day in preparation for the trial tests (Figure 3-6).

Figure 3-6. Contaminated Soil Being Moved into Storage Tents, UMDA

3.2.3 Trial Tests

Prior to full-scale composting, three small trial test windrows were constructed in the CSSB. BSI conducted the trial tests to: (1) determine the timeliness and effectiveness of composting at reducing TNT and RDX concentrations; (2) correlate field data (using EPA Method 8515 for TNT and Method 8510 for RDX) and laboratory data (using EPA Method 8330) of the test windrows; (3) plan alternative actions, if necessary, to improve degradation rates if action levels of 30 ppm for TNT and RDX were not achieved within 40 days; and (4) determine the optimum turning frequency for full-scale operations. BSI monitored a number of physical characteristics during the trial tests including temperature, pH, moisture level, and gas/vapor production. These physical tests helped BSI determine optimum pile turning frequency.

During the trial test, BSI employed an intense regimen of sampling and analysis, using EPA Method 8515 for TNT and Method 8510 for RDX for onsite analysis and Method 8330 for laboratory confirmational analysis. The increased number and frequency in sampling was performed to determine TNT and RDX concentrations at specific sampling locations and time intervals within the three windrowed compost piles. Three test piles were prepared, in part, to accommodate three different turning strategies. The loading ratio of contaminated soil (30%) to amendments (70%) were the same for all three test piles (see below). The turning frequencies for the first two windrows were 24- and 72-hours, while the third windrow underwent a varied turning cycle: every 24 hours for the first 10 days, every 72 hours for the next 10 days, and at 168 hours for the final 10 days. Samples were taken and analyzed from all of the windrows at the start of the test period and then at 5-day intervals for 30 days until the average concentrations of TNT and RDX were determined to be statistically below 30 ppm. The optimum turning frequency was the varied turning cycle, with frequent turning during the first 3 to 5 days followed by less frequent turning. Frequent turning of the windrows improves the biodegradation process and is most effective over the initial 3 to 5 days when the decomposition rate is greatest. As the process continues, the biodegradation process is not affected by a reduction in the turning frequency.

The trial tests, consisting of 120 cy of contaminated soil (each windrow containing 40 cy of contaminated soil), were conducted using 30 percent soil by volume, with the remaining 70 percent composed of amendments. BSI blended the amendments at approximately a 1:3:5.4:5.4:6.5 ratio of chicken manure:potato waste:alfalfa:sawdust:cow manure. BSI used the same soil loading rate and the same amendments at the same ratio used in a previous preliminary treatability study performed at UMDA.

The trial tests began on March 20, 1995, after all necessary equipment had been checked and calibrated and adequate amendments had been bought, delivered, and properly blended (specific procedures and equipment used in the composting process employed at UMDA are discussed in Section 3.2.4). By April 10, 1995, (11 days after initiation of composting) onsite analysis of the trial windrows by EPA Method 8515 for TNT and Method 8510 for RDX indicated that virtually all contaminants were at nondetectable levels. BSI took confirmatory samples to verify cleanup levels via EPA Method 8330 on April 13, 1995. The trial tests were completed on April 19, 1995.

As required by the contract, BSI prepared and delivered the second RAMP (RAMP II) which incorporated the results of the trial tests as well as comments regarding RAMP I on April 24, 1995. Draft RAMP II included a Production Composting Treatment Plan and Revegetation Plan to effect contract closeout. After USACE review and comment, a final RAMP II was prepared, submitted, and approved on July 3, 1995, clearing the way for full-scale production composting to begin.

3.2.4 Full-Scale Composting

While the trial test confirmed the prescribed amendment mixture, soil loading rate, moisture content (30 to 35 percent) by weight, and turning frequency (every 24 hours the first 5 days followed by less frequent turning on subsequent days), it also revealed that the originally scheduled processing time could be significantly reduced from 40 days to approximately 22 days (8 to 10 days of which were spent waiting for offsite laboratory confirmatory analysis). BSI calculated the total contaminated soil to be 10,969 cy (as opposed to WCC's estimated volume of 10,845 cy). BSI, therefore, planned to construct 13 windrow batches, each containing 810 cy of soil (10,530 cy) and 1 batch containing 439 cy. These volumes were calculated based on the operational constraints of the apparatus that was used to turn windrows during the trial tests, which were conducted within the 200-foot by 90-foot CSSB. Because Phase I work started prior to the contract award of Phase II, there was no interface between the Phase I and Phase II contractors. Consequently, the CSSB was not designed to accommodate the turning radius of BSI's specialized turning machine (the "Wendy"). BSI began full-scale production composting on July 18, 1995.

The Process Flow Diagram shown in Figure 3-7 depicts the entire process used for all 14 batches, beginning with preparatory soil screening in the upper left corner. BSI determined that screening conducted during Phase I was inadequate for composting. All contaminated soil was rescreened to remove large chunks of construction debris and rocks (Figures 3-8 and 3-9).

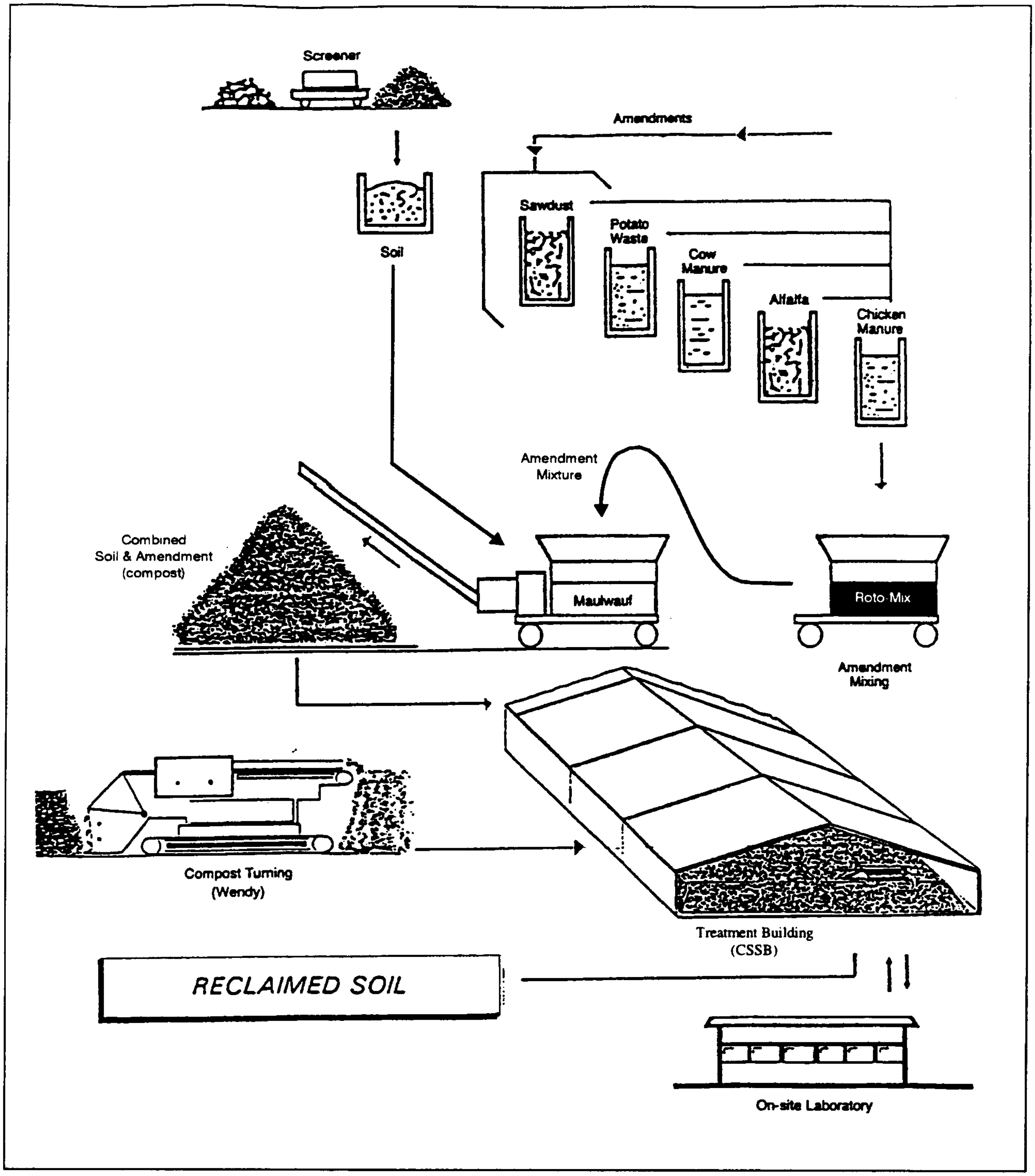

Figure 3-7. Process Flow Diagram, UMDA

Source: (2)

Figure 3-8. Screening Oversized Rocks and Concrete, UMDA

Figure 3-9. Screened Soil Inside Storage Building, UMDA

With amendments procured and stored (Figures 3-10 and 3-11), mixing of the prescribed blend was initiated with retrieval of the selected amendment from the appropriate bin (Figure 3-12). The amendments were always premixed before they were mixed with the contaminated soil. This two step process encouraged early initiation of microbial activity. The mixing of amendments was performed using the front-end loader/Roto-Mix system. Amendments were loaded into the Roto-Mix hopper which was mounted on four load cells connected to a digital scale allowing precise and rapid batching of each amendment. BSI established a correlation between weight of amendments and required volumes. Once loaded, the Roto-Mix combined the three actions of folding, cutting, and shearing to ensure thorough amendment homogenization (Figure 3-13).

Figure 3-10. Vendor Delivering Alfalfa, UMDA

Figure 3-11. Stored Amendments Separated by Ecology Blocks, UMDA

Figure 3-12. Pulling Amendments for Mixing, UMDA

Figure 3-13. Mixed Amendments, UMDA

The mixed amendments were then loaded into a "maulwauf" soil mixing unit located on the Materials Processing Area (MPA) (Figure 3-14) with the front-end loader. Screened contaminated soil was also loaded into a soil hopper driven by the maulwauf. The maulwauf conveyed the amendment mixture to a shredder chamber, where it was mixed with contaminated soil in a 7:3 volumetric ratio. The compost was then carried by belt conveyor and discharged onto the MPA for loading into the CSSB for treatment. Using a front-end loader, the material was arranged into a windrow measuring 165 feet by 55 feet by 7 feet.

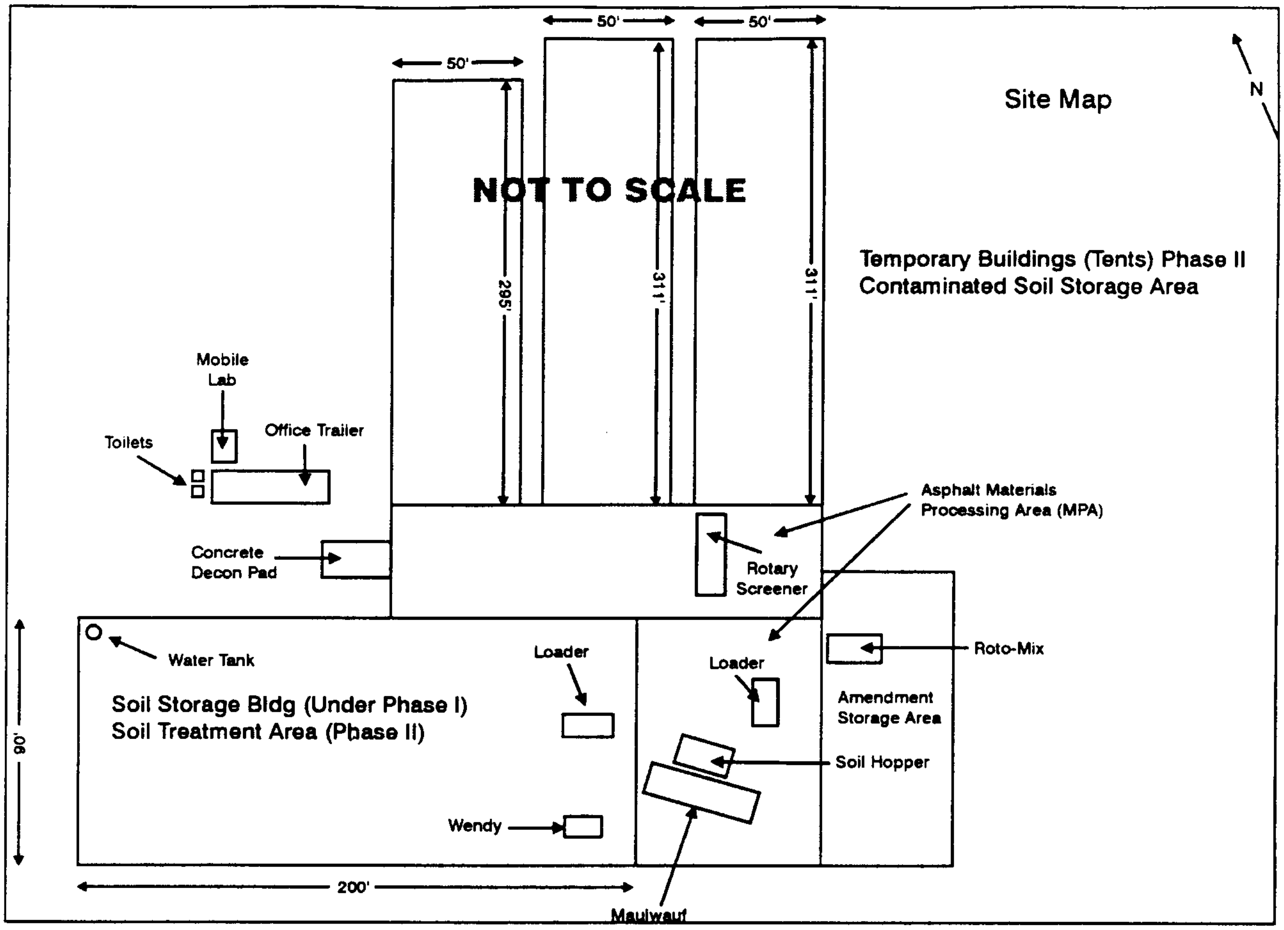

Figure 3-14. Site Map, UMDA

To ensure compost homogenization, oxygenation, and sufficient contact between microorganisms and contaminants, the windrows were turned every 24 hours for the first 5 days of treatment then less frequently on the following days. BSI used a compost turning machine, called the "Wendy" (Figure 3-15) to turn the windrows. The process of turning introduced oxygen and removed heat. Although the compost turning machine leaves the windrow largely intact upon turning, any necessary reshaping was done by a front-end loader.


Figure 3-15. Turning of a Windrow, UMDA

3.2.5 Chemical Analysis

During the course of the composting operation, monitoring of the material for temperature, percent oxygen, percent moisture, pH, and explosives concentration was performed regularly. Temperature was monitored intermittently via probes placed in and along the length of the pile. Oxygen, which had been determined from previous studies to drop to an equilibrium level rapidly after turning, was monitored daily using a hand-held meter attached to a probe. Percent moisture, as well as pH, were monitored twice a week with moisture being added as needed to maintain optimum conditions.

The remaining contaminant level was determined using EPA Method 4050 for TNT and Method 4051 for RDX during onsite analysis. EPA Method 8330 was used for confirmatory laboratory analysis. Although Methods 8515 and 8510 were effective in determining contaminant levels in explosives-contaminated soil, Methods 4050 and 4051 exhibited better correlation with laboratory analysis data (Method 8330) after nitrogen rich amendments are mixed with the contaminated soil. The colorimetric technique used in Methods 8515 and 8510 experienced interference from the nitrogen rich amendments. In contrast, the immunoassay technique used in Methods 4050 and 4051 takes advantage of the ability of antibodies to selectively bind to specific target compounds present at low concentrations in the sample matrix. This change in onsite analysis was approved by USACE on June 26, 1995, so subsequent onsite analyses were conducted using Method 4050 for TNT and Method 4051 for RDX, while Method 8330 was still used for confirmatory laboratory analysis. In accordance with the Phase II Contractor Quality Control Management Plan, onsite analyses for TNT and RDX were conducted after the soil had been initially mixed with the amendments and periodically thereafter until the cleanup goal of <30 ppm was met. Average concentrations of contaminant taken from archived compost samples collected from day 0 during trial test composting were 190 ppm for TNT and 227 ppm for RDX. Once the cleanup level was attained, as indicated by onsite analysis (Figure 3-16), confirmational sampling was conducted. Two discrete random grid samples (Figure 3-17) representing a maximum of 30 cy of contaminated soil (grid size) were taken from each grid and sent to an offsite chemical laboratory for confirmatory analysis using EPA Method 8330.

Figure 3-16. Onsite Analysis (TNT/RDX), UMDA
Using test protocols based on Methods 8515 (TNT), and 8510 (RDX).

Figure 3-17. Split Sample Preparation, UMDA
Preparation as required by QA/QC plan for offsite confirmatory analysis using Method 8330.

A grid is equivalent to 30 cubic yards of contaminated soil, so a batch containing 810 cubic yards of contaminated soil would have 27 grids. Two random samples are taken from each grid over the whole windrow for a total of 54 samples. If only one or two grids fail the <30 ppm cleanup level, then only those grids are re-sampled. If more than two grids fail, then additional treatment is resumed to facilitate further degradation before additional sampling occurs.

BSI experienced only two failed grids on separate windrows during treatment. In Batch 3, a grid sample showed mean concentrations of both TNT and RDX at 33.5 ppm. A second sampling indicated that TNT and RDX were below 30 ppm, suggesting that the first sample contained an explosive speck. A second instance of a failed grid occurred in Batch 11 (see Figure 3-18), with concentrations of 46.5 ppm for TNT and 61 ppm for RDX. The other 26 grids in Batch 11 were below the 30 ppm action level. The failed grid was segregated from the other batches and incorporated into a subsequent batch for further treatment. Once laboratory analysis confirmed that both TNT and RDX were below 30 ppm, the composting batch was transferred out of the CSSB (Figure 3-19) and stockpiled under cover (Figure 3-20) for eventual return to the excavated area.

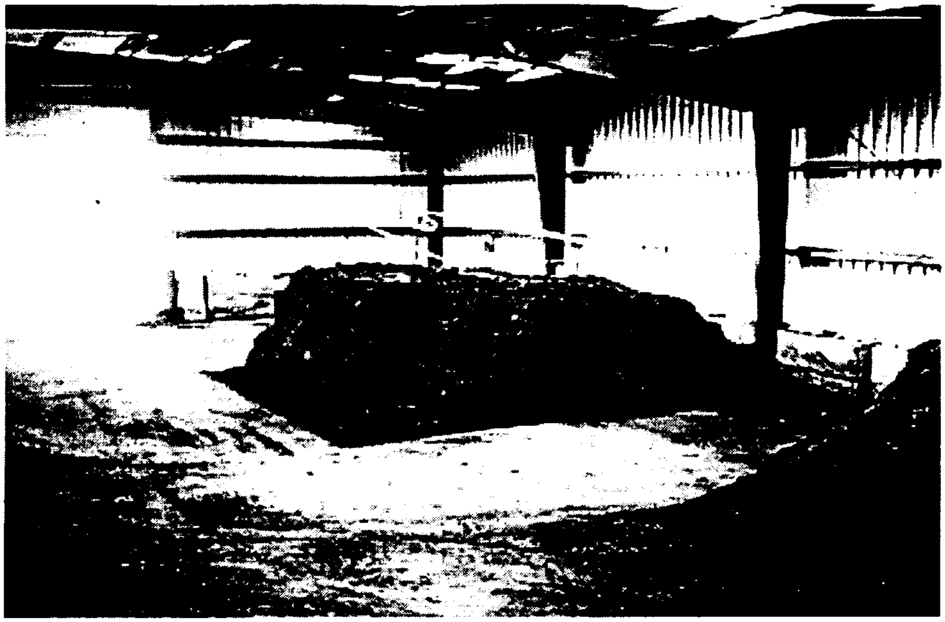

Figure 3-18. Segregated Failed Grid Batch, UMDA

Figure 3-19. Loading Treated Soil, UMDA

Figure 3-20. Temporary Treated Soil Stockpile, UMDA

Batch 1 was completed on August 23, 1995, 23 days after windrow construction. Similar processing times for the remaining batches have been recorded. Project completion has been revised to occur on or around September 1, 1996, approximately one year ahead of the original project schedule.

3.2.6 Demobilization/Site Restoration

Once a composting batch is completed, the treated soil is transferred by dump truck to a final stockpile area adjacent to the lagoons. The USACE will transfer the soil back into the lagoons after a separate groundwater remediation effort is complete. Because the volume of material will have increased by approximately 75 percent due to the addition of the amendments, a mounding effect will occur. This mound is anticipated to be capped with a foot or two of common borrow, graded, and seeded with rye or other suitable vegetative cover. Additional closeout activities will include the decontamination and demobilization of all equipment, disconnection of utility hookups and services, and recycling of all asphalt materials. Any waste will be removed from the site and use areas will be restored. BSI's submission of a closeout report is anticipated on or about September 1, 1996. Table 3-2 shows the timeline of Phase II activities.

Table 3-2. Phase II—Timeline

Activity	Start Date	End Date
Notice to proceed	June 13, 1994	—
Site Setup	December 19, 1994	February 9, 1995
Trial Tests	March 20, 1995	April 19, 1995
Full-scale Composting	July 18, 1995	September 1996*
Chemical Analysis	March 20, 1995	September 1996
Demobilization/Site Restoration	September 1996*	December 1996*
*Anticipated		

4.0 Summary of Costs

4.1 Remedial Action—Work Breakdown Structure (RA-WBS) Methodology Overview

All cost data collected for this report have been organized according to the format specified by the Remedial Action-Work Breakdown Structure (RA-WBS). This cost methodology provides a common language that can be used to ensure clear communications among those who work on a project, including accountants, supervisors, foreman, engineers, regulatory officials, and legal professionals. The Interagency Cost Estimating Group (ICEG) developed this method of cost reporting for tracking full-scale remediation projects because it facilitates widespread use and comparability across agencies and various media. The ICEG is composed of cost and project management professionals with a broad spectrum of experience in environmental restoration. Those professionals represent the U.S. Environmental Protection Agency, the U.S. Department of Energy, the U.S. Army Corps of Engineers, the Naval Facilities Engineering Command, and the U.S. Air Force. The group has been augmented at times by individuals from the private sector and other Federal agencies.

The standard RA-WBS contains a comprehensive list of predefined cost elements (tasks, items, or products) that have been identified through experience as required to accomplish a typical project. The list can be arranged in spreadsheet format and defines each cost element, including its unit of measure, and assigns each element a unique number composed of up to five sets of two-digit numbers. The spreadsheet organizes the elements such that related items are grouped together to form a hierarchy. The lower the level on the hierarchy, the more detailed the items become. The RA-WBS hierarchy has five levels of detail. Level 1 defines the project as a hazardous, toxic, and radioactive waste (HTRW) remedial action project. Level 2 lists major work categories generally found in a remediation construction project. At Level 3, items that are used to accomplish Level 2 categories appear, while Levels 4 and 5 represent further detail of cost items associated with the project. Table 4-1 provides an example of a completed RA-WBS for a fictional project.

Table 4-1. Work Breakdown Structure Reporting Example

PROJECT COSTS (X $1,000)						
		COST	COST	COST	UNITS	UNIT COST
33.01	MOBILIZATION AND PREPARATORY WORK	$ 48				
33.01.02	Mobilization of Personnel		$ 48			
33.01.02.01	Relocation of Personnel			$ 48	4	12/EA
33.03	SITE WORK	$ 400				
33.03.04	Roads/Parking/Curbs/Walks		$ 100			
33.03.04.04	Concrete Surfacing			$ 50	100	0.5/CY
33.03.04.10	Signs			$ 11	22	0.5/EA
33.03.04.90	Sewage Vents			$ 39	3	13/EA
33.03.05	Fencing		$ 50			
33.03.05.01	Fencing			$ 45	4500	0.01/LF
33.03.05.02	Gates			$ 5	100	0.05/LF
33.03.10	Fuel Line Distribution		$ 250			
33.03.10.01	Fuel Line Distribution			$ 200	20000	0.01/LF
33.03.10.03	Connections/Fees			$ 20	50	0.4/EA
33.03.10.30	Tests			$ 30	5	6.0/EA
33.05	SURFACE WATER COLLECTION AND CONTROL	$ 50				

An important feature of the RA-WBS is the ability to add additional cost categories where needed to customize the cost reporting. These cost elements are added by the user into "blank" areas located throughout the structure. For example, preparation of a RAMP did not appear as a line item in the existing RA-WBS structure and was added in the appropriate location under Element Number 33.01—Mobilization and Preparatory Work. Because windrow composting of explosives-contaminated soils is considered an innovative technology, several cost elements were not included in the existing structure. Instead, they were added in appropriate locations using the "nonstandard element" notation indicated by the number 9x, where x was replaced with a digit corresponding to the number of item(s) added. Separate WBS spreadsheets were prepared for Phase I and Phase II.

4.2 Assumptions and Limitations/Level of Documentation

Cost data used in this report came exclusively from the original contract, contractors' requests for payment, and the corresponding payment records prepared by USACE. Contract files were accessed to determine original contract pricing as well as financially significant modifications to the contracts. The format in which the contractors provided cost data was not readily converted for inclusion into the RA-WBS and as a result, caused some difficulty. Future data collection could be facilitated if remedial action contractors reported cost in the RA-WBS or similar format.

As this project was funded via government appropriations on a fiscal year basis, no debt service or carrying cost is included. Because projects conducted at other government installations may also be subject to the Resource Conservation and Recovery Act (RCRA) facility design requirements applied at UMDA, any discussion of potential cost reduction associated with variations of applicable regulation(s) has been foregone. It is important to note, however, that at an EPA Regional Administrator's discretion, the RCRA facility design requirements may be waived.

Additional sources of information for this cost report included the Best and Final Offer (BAFO) solicitation packages submitted on behalf of each contractor, RAMPs submitted under the respective contracts, monthly progress reports, and daily and weekly quality control reports provided by the contractors and onsite USACE representative. To the extent practicable, this report uses actual payment figures.

4.2.1 Fixed Costs vs. Variable Costs

This report identifies the various cost elements as either "fixed" or "variable." As used in this report which applies to the UMDA remediation effort, fixed costs refer to those costs incurred at UMDA that do not vary with the volume of soil treated. Mobilization and Preparatory Work represents a fixed cost because this activity must be done to accomplish the work, and its cost is irrespective of soil volume. That is, mobilization and preparatory work must be done to treat 1 ton or 10,000 tons of soil, and its dollars will remain relatively the same for either volume. This report considers analytical work (Monitoring, Sampling, Testing, and Analysis) as a variable cost since the total dollars associated with this cost element is directly related to the volume of soil; that is, more soil increases the number of tests, and inherently the total dollars. The sum of all of the fixed costs represents the minimum cost for operations at UMDA. Variable costs (e.g., amendments, sampling) are calculated by multiplying the unit variable cost with the number of units (e.g., tons, cubic yards, samples) processed. Total cost for processing soil at UMDA is then the summation of all variable costs and all fixed costs. At UMDA, the unit cost (dollars per ton) for treatment of small soil volumes would be high due to the high up-front fixed costs and low treated soil volume. The unit cost for treating larger soil volumes at UMDA increases marginally at first, then levels off as fixed costs are spread over static unit cost of processing soil.

To estimate the unit cost at other sites, some cost elements identified here as "fixed" for UMDA will change based on site-specific conditions. Therefore, cost elements identified as "fixed" for UMDA will not represent the actual cost at another site. This report identifies Site Work as a fixed cost, because the cost for clearing and grubbing of the area did not change with the volume of soil treated. However the fixed cost for Site Work at UMDA ($526,294, combined cost for Phase I and Phase II) will not be the same for another site unless it has the same vegetation, same soil, same topography, and same surface area as UMDA. A site with considerable vegetation, high slopes, and no existing roads will experience a higher cost for site work than a site that is clear of vegetation, relatively flat, and with existing roads.

The unit variable costs (e.g., cost of each laboratory sample, cost of alfalfa per ton) at UMDA can be translated to other sites with similar conditions. Unit cost for some of the variable cost elements will also vary at other sites according to factors such as type of contaminants and concentration of contamination, type of amendments used, availability of amendments, cost of amendments, and regional labor rates. These factors will cause the unit variable costs to differ from UMDA even before factoring in the number of units (e.g., soil volume, number of samples).

4.3 Cost Breakdown—Phase I

Each of the eight general work areas appearing in the RA-WBS for Phase I is represented in Table 4-2 below indicating activity, total cost, percentage of Phase I cost, as well as percentage of the combined Phase I and Phase II cost ($5,131,106). Table 4-2 identifies the cost elements as fixed or variable costs. Fixed costs do not vary with project duration or the volume of contaminated soil to remediate, while variable costs change according to site specific variables (e.g., nature and extent of contamination, soil characteristics, climatic conditions) and with the soil volume to remediate (i.e., overall project cost rises with increased volume of soil). Figure 4-1 shows graphically the HTRW level 2 costs.

Table 4-2. Phase I Cost Breakdown

Work Area	Activity	Cost	% of Phase I Cost	% of Phase I and II Cost
33.01	Mobilization and Preparatory Work [1]	$257,000	19.47%	5.01%
33.02	Monitoring, Sampling, Testing, and Analysis [2]	$87,478	6.63%	1.70%
33.03	Site Work [1]	$506,294	38.35%	9.87%
33.08	Solids Collection Containment [2]	$403,578	30.57%	7.87%
33.10	Drums/Tanks/Structures/Misc. Demolition and Removal [2]	$39,812	3.02%	0.78%
33.20	Site Restoration [1]	$21,000	1.59%	0.41%
33.21	Demobilization [1]	$5,000	0.38%	0.10%
PHASE I TOTAL COST		**$1,320,162**		**25.73%**

Notes:

1 Fixed Costs
2 Variable Costs

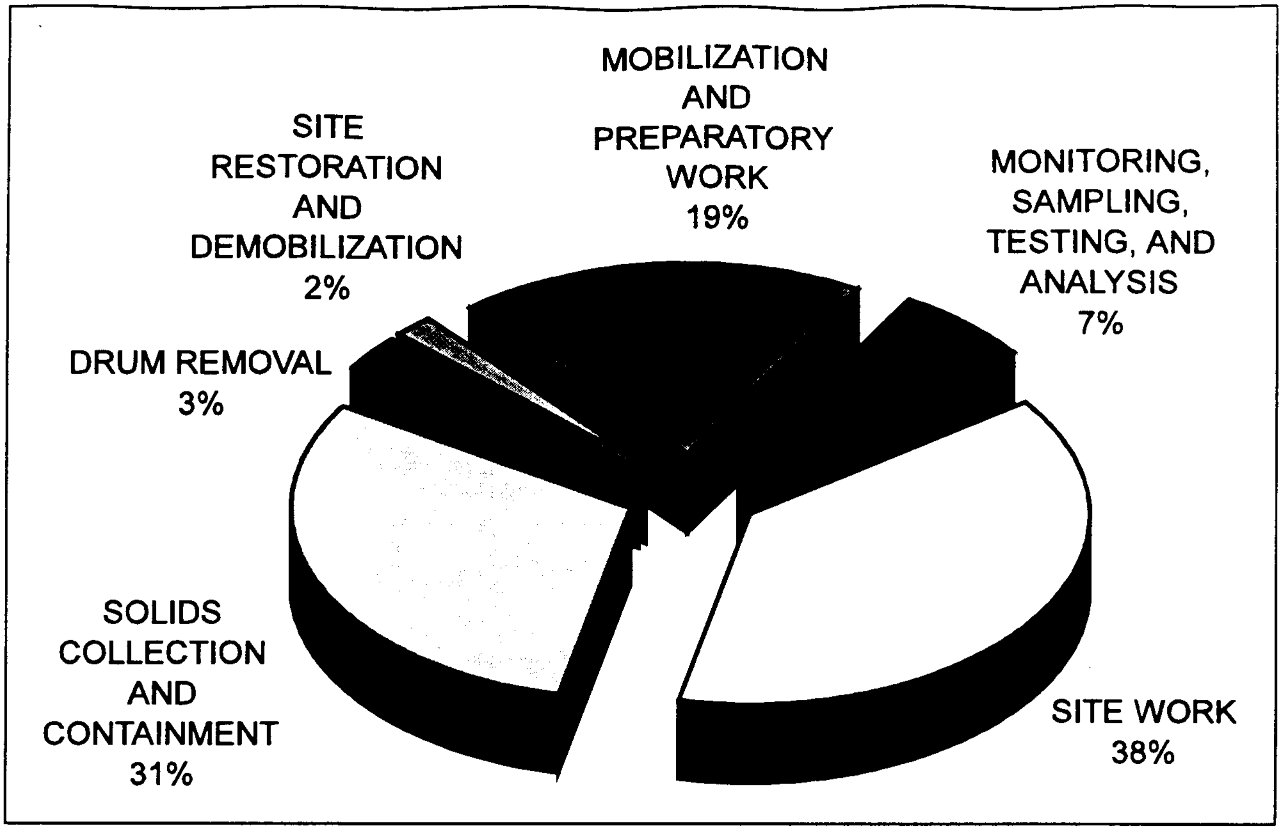

Figure 4-1. Phase I—Total Cost

The four largest areas of cost concentration occurring in Phase I are: Site Work at 38 percent, Solids Collection and Containment at 31 percent, Mobilization and Preparatory Work at 19 percent, and Monitoring, Sampling, Testing, and Analysis at 7 percent. The balance of the general work categories in Phase I comprise approximately 5 percent of the Phase I cost (Drums/Tanks/Structures/Miscellaneous Demolition and Removal at 3 percent, Site Restoration and Demobilization at 2 percent). Drum removal was unique to UMDA and will probably not occur at other sites.

Given that the primary thrusts of Phase I were to construct a storage building, excavate the contaminated soil, and relocate the material to the storage building, the distribution of the costs are consistent with the tasking.

The breakdown of cost provided via record of payment and request for payment histories, did not always lend itself to ready categorization in the RA-WBS format. RA-WBS elements 33.01.01—Mobilization of Construction, Equipment & Facilities and 33.01.02—Mobilization of Personnel had to be included in the subsequent RA-WBS element 33.01.04—Setup/Construct Temporary Facilities due to WCC's practice of grouping these costs together.

Additional considerations in examining costs associated with Phase I activity at UMDA include RA-WBS work area 33.03, Site Work, where the demolition cost associated with the removal of the asphalt pad appears. Depending on the facility, existing pad sites may be present and should be included in the site selection evaluation to avoid or reduce demolition cost. RA-WBS category element 33.03.02, Clearing and Grubbing, was not applicable at UMDA. Because of the climate at UMDA (semi-arid cold desert) and sparse flora, very little work was required to prepare the site for activity. This cost may differ at another facility with rugged terrain or heavy vegetation or both. Managers considering project design and project costs should weigh the cost of treating onsite versus transporting soil to a more suitable site for composting, if they expect extensive site work.

RA-WBS category element 33.03.90 represents another instance where a lump sum entry was provided by WCC under the heading "General Field Requirements" with no further clarification. The standard RA-WBS does not include such a heading, therefore, it was grouped under site work, given its name, but was entered as a 9x or "nonstandard element" in the RA-WBS. Due to lack of data, no further cost differentiation was possible in this area.

The chain of events associated with the increased soil volume, described in Chapter 3, initially appears in the Phase I RA-WBS work area 33.02, Monitoring, Sampling, Testing, and Analysis under category element 33.02.09, as additional sampling totaling $9,920. The increased excavation and transport costs for this additional soil appear later in RA-WBS work area 33.08—Solids Collection and Containment under subelements 33.08.01—Excavation of Contaminated Soil, 33.08.90—Screening, and 33.08.91—Transport Contaminated Soil to Storage Building. Although dispersed between the three subelements, this activity accounted for the most significant contract modification to Phase I.

4.4 Cost Breakdown—Phase II

Each of the eight general work areas appearing in the RA-WBS for Phase II is represented in Table 4-3, indicating activity, total cost, percentage of Phase II cost, and percentage of the combined Phase I and II costs ($5,131,106). Table 4-3 also identifies the cost elements, or activities, as fixed or variable costs. Figure 4-2 graphically identifies the primary cost elements in Phase II.

Figure 4-3 illustrates total project cost including Phase I, Phase II, and all work on behalf of USACE in preparing, supervising, and administering the Remedial Action Contracts.

Table 4-3. Phase II Cost Breakdown

Work Area	Activity	Cost	% of Phase II Cost	% of Phase I and II Cost
33.01	Mobilization and Preparatory Work [1]	$1,258,701	33.03%	24.53%
33.02	Monitoring, Sampling, Testing, and Analysis [2]	$423,481	11.11%	8.25%
33.03	Site Work [1]	$20,000	0.52%	0.39%
33.11	Biological Treatment [2]	$1,989,454	52.20%	38.77%
33.19	Disposal (Commercial) [1]	$8,950	0.23%	0.17%
33.20	Site Restoration [1]	$9,960	0.26%	0.19%
33.21	Demobilization [1]	$78,480	2.06%	1.53%
33.90	Settle Miscellaneous Claims [2]	$21,918	0.58%	0.43%
PHASE II TOTAL COST		**$3,810,944**		**74.27%**
TOTAL COST PHASE I&II		**$5,131,106**		

Notes:
1 Fixed Costs
2 Variable Costs

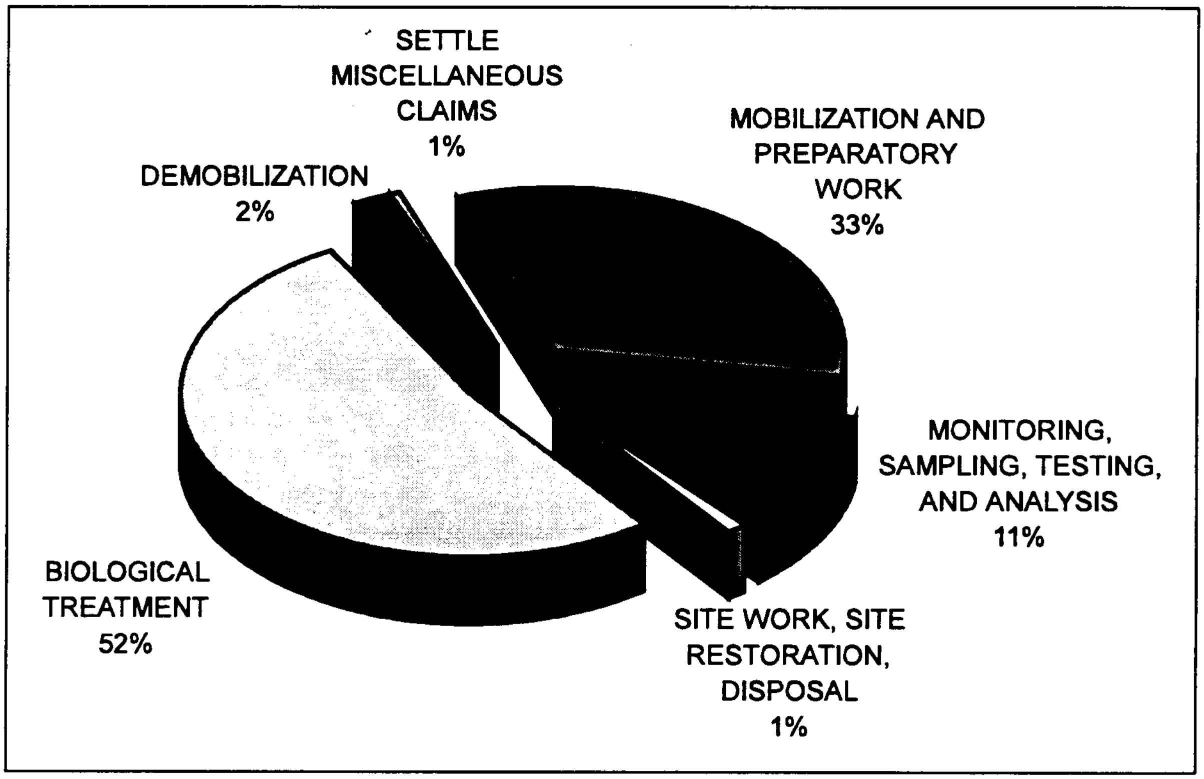

Figure 4-2. Phase II—Total Cost

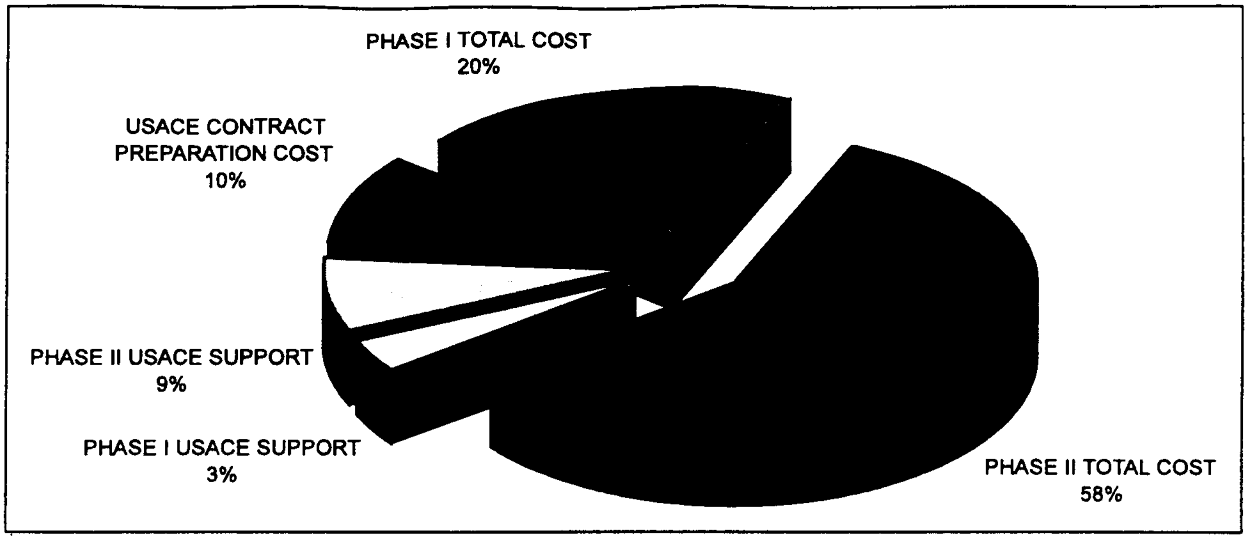

Figure 4-3. Total Cost by Phase

The three largest areas of cost concentration occurring in Phase II include Biological Treatment at 52 percent, Mobilization and Preparatory Work at 33 percent, and Monitoring, Sampling, Testing and Analysis at 11 percent. The balance of the general work areas in Phase II comprise four percent of the Phase II cost (Demobilization at two percent, Site Work, Site Restoration and Disposal [Commercial] at one percent, and Settlement of Miscellaneous Claims at one percent).

Given that the primary thrusts of Phase II were to perform (1) trial tests to ascertain optimization of amendment mixture, equipment, and operating procedures; (2) full-scale production composting; and (3) demobilization and restoration, the cost elements of biological treatment, mobilization, and preparatory work and analytical chemistry are consistent with the tasking.

As mentioned in Chapter 2, much of the duplicative effort occurred at the beginning of Phase II. Within the RA-WBS category elements 33.01.03 through 33.01.05, numerous instances of duplication are evident. Considerable duplicative effort and cost might have been avoided if a single procurement had been used.

Furthermore, the chain of events associated with the increased soil volume resurfaces in RA-WBS category element 33.01.04—Setup/Construct Temporary Facilities, where the $486,970 for leased storage tents appear. This item constitutes the second largest modification to the Phase II contract, surpassed only by the $697,642 cost increase for the biological treatment and testing of the additional soil. Another expenditure that was incurred as a result of the additional soil excavation was the cost of transferring it from the temporary pile into the storage tents. This activity cost $66,101.

RA-WBS category element 33.02.06—Sampling Soil and Sediment (onsite analysis) and RA-WBS category element 33.02.09—Laboratory Chemical Analysis represent additional cases where only lump sum entries were provided by BSI with no further clarification. Although dedicated categories exist within the standard RA-WBS for each of the entries, further detail pertaining to cost per sample and number of samples taken would be helpful in future cost estimating.

4.5 Unit Cost Breakdown

Unit cost for the UMDA remediation by windrow composting is $346 per ton of contaminated soil (Total Phase I and Phase II cost: $5,131,106 ÷14,808 tons of contaminated soil). Tonnage was derived using 100 pounds per cubic foot of soil present at the site, as communicated via phone by U.S. Army Corps of Engineers on June 20, 1996 (6).

4.5.1 Lowest Unit Cost Possible

The use of two contractors at UMDA resulted in some duplication of effort, and therefore costs. Although this two-phase approach at UMDA was unavoidable, other sites should attempt to use a single contractor for both excavation and remediation. The unit cost of $346 per ton of contaminated soil at UMDA incorporates this duplication of costs, particularly in the areas of Mobilization and Preparatory Work, Site Restoration, and Demobilization. In addition, the lack of interface between the two contractors resulted in additional work and added costs (e.g., re-screening the soil, temporary storage tents). By theoretically eliminating (or reducing) some costs associated with duplicated efforts, the unit cost could be as low as $299 per ton of contaminated soil at UMDA.

A single contractor would require only one mobilization, one site restoration, and one demobilization. At UMDA the demobilization of Phase I and the mobilization of Phase II caused some significant overlap. RA-WBS work category 33.01, Mobilization and Preparatory Work for Phase I could be reduced by $154,000, retaining the higher cost of mobilization in Phase II plus the costs for the RAMP in Phase I. Though a single contractor may only prepare a single RAMP to address both excavation and remediation, that RAMP would be extensive; thus, the cost of preparing the additional RAMP in Phase I is retained in the mobilization cost. RA-WBS work categories 33.20 and 33.21, Site Restoration and Demobilization, could be reduced by $9,960 and $5,000, respectively (these reductions are the lower of Phase I and Phase II costs for these elements).

Additionally, there are some costs in Phase II that are incurred as a result of the lack of interface between the two contractors. Because Phase I work started before the Phase II contract was awarded, WCC could not anticipate the appropriate size of the CSSB to accommodate the size and turning radius of BSI's specialized equipment. The lease of the temporary tents ($486,970) was somewhat excessive, considering that the overflow of excavated soil was adequately stored outside with a reinforced 18-mil polyethylene liner for cover on an asphalt pad by the Phase I contractor. The contaminated soil in the soil storage building could have been stored in a similar fashion, with a reduced cost. This would also reduce the cost of transferring the soil (say, in half) by only moving soil in the building.

Alternatively, a future contractor may evaluate the feasibility of simultaneously excavating and remediating. A backhoe operator would excavate one batch of soil at a time for processing. During the biodegradation period of a batch, onsite analysis could be done in the contaminated area to identify the area to excavate for the next batch. This "assembly line" approach would eliminate the need for any storage facility.

Finally, the Phase II contractor had to re-screen the contaminated soil because the Phase I contractor (already paid in full by USACE to do the screening) did not screen to an adequate particle size. This screening added $16,000 to the Phase II contract, which could have been avoided with a single contractor.

Table 4-4. Potential UMDA Cost Savings

WBS #	Activity	Cost
33.01.04	Mobilization and Preparatory Work: Setup/Construct Temporary Facilities	$154,000
33.20	Site Restoration	$ 9,960
33.21	Demobilization	$ 5,000
33.01.04.91	Temporary Storage Tents	$486,970
33.01.90	Transfer Soil into Storage Tents	$ 33,050 (50% of $66,101)
33.01.91	Additional Screening to Remove Concrete Debris	$ 16,000
	TOTAL Potential Cost Savings	$704,480

Considering the potential cost savings identified in Table 4-4, above, the unit cost of the UMDA windrow composting could be as low as $299 per ton of contaminated soil, a 14% cost savings.

4.5.2 Unit Variable Cost

Unit cost has been used in this report to mean total cost of remediation per ton of contaminated soil. In addition, each cost element and subelement can be broken into a unit dollar cost. In Appendices A and B, unit costs are provided for variable cost elements such as amendments and analytical testing, so that they may be applied to other sites. Alternatively, fixed costs are generally provided in a lump sum value. At UMDA, fixed costs account for 58% ($2,165,385) of the combined Phase I and Phase II total cost. This value represents the minimum cost to operate before any soil is treated.

Table 4-5 identifies some of the variable cost elements, with the associated unit cost. Managers of other sites similar to UMDA can estimate variable costs by scaling the unit variable costs, shown below in Table 4-5, according to number of samples, volume of soil, etc. Some unit costs below will vary at different sites according to different factors (e.g., test methods used, types of amendments used, availability of amendments, etc.).

Table 4-5. Examples of Unit Variable Costs at UMDA

WBS #	Activity	Units	Cost/Unit
33.02.06	Sampling Soil and Sediment (onsite analysis)		
	First 61 Samples	EA	$ 28
	Over 61 Samples	EA	$ 25
33.02.09	Laboratory Chemical Analysis		
	First 42 Samples	EA	$ 225
	Over 42 Samples	EA	$ 250
33.08.01	Excavation of Contaminated Soil	CY	$ 17
33.08.90	Screening	CY	$14.02
33.08.91	Transport Contaminated Soil to Storage Building	CY	$ 5.59
33.11.07.01.08	Amendments	LS	
	Sawdust	CY	$16.75
	Alfalfa	TON	$109.00
	Chicken Manure	TON	$48.45
	Cow Manure	TON	$16.00
	Potato Waste	TON	$22.50

4.6 Sensitivities

A number of factors can directly or indirectly affect costs. These factors include physical parameters such as climate, soil characteristics, and contaminant level as well as economic parameters such as labor rates, availability and cost of amendments, and site accessibility and infrastructure. Some of these factors are discussed below.

Climate and Soil

At UMDA, the semi-arid cool climate—coupled with the sparse vegetation of grasses and low brush—allowed for a fairly low preparatory site work cost. The soils, which generally consist of fine to coarse sands and gravels with an occasional lens of silt, were also readily excavated. Other sites will naturally vary in climate (precipitation, temperature, wind conditions, and relative humidity) and soils (clay content, rock, and chemistry). The sites will therefore require more extensive clearing, grading, and excavation with higher associated cost.

Labor

The cost of labor can vary considerably by location. Qualified equipment operators are required to operate all the machinery used in the windrow composting process. Typically, when heavy construction equipment is bid, the price includes the operator; however, at UMDA the "maulwalf" and "Wendy" machines were classified as specialized equipment and commanded an even higher premium for their operation. Attention should be given to becoming familiar with applicable wage rates in the region of activity and ensuring qualified individuals are available.

Amendments

Amendment availability and cost are significant when reviewing composting cost variables. Two important considerations are the proximity and seasonality of the materials to be used. At UMDA, the majority of the amendments were readily available in the Umatilla area. Several large potato processors were nearby, and processing occurred year-round. The adjoining counties also contained a number of livestock feedlots, making cow manure readily available. A large commercial egg supplier was present in Pasco, Washington, where a constant supply of chicken manure was available; however, transportation from the supplier for all amendments to the site (approximately 50 miles) did influence cost. Alfalfa was grown locally with harvest occurring from late June to early September. Alfalfa was available year-round, but in limited quantities and elevated prices. Sawdust was the most difficult amendment to obtain because logging operations had ceased in the immediate vicinity. Although relatively unaffected by seasonal changes, the sawdust had to be transported from Hood River, Oregon, a distance of approximately 100 miles, thereby influencing its cost. Availability, seasonality, and quality and consistency are equally important when considering amendment materials and sourcing.

Site

Site location, accessibility, and infrastructure also contribute to cost. Terrain posed little or no difficulty at UMDA, given the modest relief characteristics, and even though the setting is rural, an adequate infrastructure is present. Paved roads are within a mile of the lagoons, with gravel roads covering the remaining distance. Sufficient water is available from the installation hydrant system, while a transformer, installed at the lagoons and tied into existing service, provides necessary power. Interstate access is immediate; UMDA is situated at the intersection of I-82 and I-84. The site should be fairly level to avoid costly earthwork and preferably cleared for the same reasons. The increase in the volume of treated soil due to the addition of 70 percent amendment should also be considered for its impact on redisposition at the site. An area within close proximity to the contaminated area would be ideal for site setup to avoid long hauling distances.

5.0 Conclusions and Recommendations

The purpose of this report is to document the costs for the first full-scale use of windrow composting to treat explosives-contaminated soils at UMDA. A previous preliminary analysis conducted for a small-scale demonstration study at UMDA estimated the unit cost for windrow composting at $326 per ton of contaminated soil for 10,000 tons of soil over a project duration of 2 years (8). This report concludes that the unit cost for full scale remediation at UMDA is $346 per ton of contaminated soil for 14,808 tons of soil over a project duration of two and a half years (from mobilization of Phase I to demobilization of Phase II). Although this report does not attempt to make an economic comparison of windrow composting to incineration, it clearly demonstrates the cost-effectiveness of this innovative technology over its historic alternative (estimated cost for incinerating approximately 14,000 tons of contaminated soil is $540 per ton [4]).

The cost data for this remediation work is presented using the RA-WBS. Table 5-1 below identifies the largest cost elements of the RA-WBS for the UMDA remediation.

Table 5-1. Summary of Largest Cost Elements

WBS Item	Activity	% of Total Phase I and Phase II Cost
33.11	Biological Treatment	39%
33.01	Mobilization and Preparatory Work	25%
33.03	Site Work	10%

The total Phase I and Phase II cost ($5,131,106) does not include the USACE cost for support (engineering, supervision, administration) and contracts (Invitation for Bid in Phase I and Request for Proposal in Phase II). The USACE total cost for "doing business" (support and contracts) at UMDA was significant at $1,385,000, or 21% of the total project cost (Phase I plus Phase II plus USACE costs). USACE costs represent fixed costs. Mobilization and Preparatory Work and Site Work also represent fixed costs that are independent of project duration or volume of contaminated soil to be treated. Biological treatment costs will vary according to site specific variables (e.g., nature and extent of contamination, soil characteristics, amendments availability, and regional labor rates) and processing rates.

Based on the results presented in this report, managers of other sites with explosives-contaminated soils can estimate the cost of remediation using the windrow composting technology. Estimates will come closest to actual costs for sites with similar site conditions (contaminated soil volumes, climate, soil type) and similar remedial action goals as UMDA. Estimates for sites with different conditions and different remedial action goals must scale subelement costs according to individual site characteristics.

In addition to documenting cost, this report provided some recommendations for possibly optimizing cost at future remediation sites. Those recommendations are re-iterated here:

- In accordance with contract requirements, the remediation contractor should perform on-site trial tests prior to full-scale production composting to: (1) ensure proper equipment operation; (2) determine effectiveness of treatment; (3) correlate field data from onsite analysis (Methods 8515 and 8510 or alternatively, Methods 4050 and 4051) with laboratory data (Method 8330); and (4) determine optimal amendments mixture, loading rate, and turning frequency. At UMDA, incorporation of trial test results increased processing rates, reduced treatment times, and created the potential for significant savings.

- Since the loading rate of amendments (70%) to contaminated soil (30%) is high, the contractor may select the specific amendments to substantially reduce cost. Both the unit amendment cost and their combined effect on reducing the composting process time reduce overall cost. For windrow composting, the contractor selects amendments based on a number of criteria including, but not limited to: carbon to nitrogen (C:N) ratio, moisture content, pH, homogeneity, texture, porosity, total metabolic energy, rate of carbon substrate use, seasonal availability, regional availability, and cost.

- Although the use of two contractors was unavoidable at UMDA, it is not recommended for future remediation sites. The USACE was approaching a deadline imposed by CERCLA to begin on-site remedial action within 15 months of the issuance of the September 1992 ROD. To avoid a NOV and other penalties, the USACE opted to perform the work in two phases. Therefore the Phase I and Phase II contractors duplicated certain cost elements (e.g., Mobilization and Preparatory Work, Site Work, Site Restoration, Demobilization). This duplication of effort is reflected in the costs.

- For future cost reporting of windrow composting operations, contractors should use the RA-WBS and report costs for subelements to the lowest level of detail to refine the effects of site-specific variables.

6.0 References

(1) Bioremediation Services Incorporated (BSI). *Phase II, Contaminated Soil Remediation, Explosives Washout Lagoons, Umatilla, Oregon.* Contract No. DACA67-94-C-0031. Remedial Action Management Plan I (RAMP I). October 1994.

(2) Bioremediation Services Incorporated (BSI). *Phase II Contaminated Soil Remediation Explosives Washout Lagoons, Umatilla, Oregon.* Contract No. DACA67-94-C-0031. Best and Final Offer (BAFO). March 1994.

(3) Bioremediation Services Incorporated (BSI). *Phase II, Contaminated Soil Remediation, Explosives Washout Lagoons, Umatilla, Oregon.* Contract No. DACA67-94-C-0031. Remedial Action Management Plan II (RAMP II). July 1995.

(4) Keehan, K. *Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes.* Chapter 5, p. 29. EPA Document No. EPA/625/R-93/013. Washington, D.C.: U.S. Environmental Protection Agency, Office Research and Development. September 1993.

(5) Logistics Management Institute. *Environmental Restoration: Remedial Action Work Breakdown Structure.* December 1994.

(6) Nelson, Mike. U.S. Army Corps of Engineers. Telephone communication with Chris Cubbage. June 20, 1996.

(7) U.S. Army Environmental Center (USAEC). *Windrow Composting Demonstration for Explosives-Contaminated Soils at Umatilla Depot Activity.* Report No. CETHA-TS-CR-93043. Prepared by Roy F. Weston, Inc. April 1993.

(8) U.S. Army Environmental Center (USAEC). *Windrow Composting Engineering/Economic Evaluation.* Report No. CETHA-TS-CR-93050. Prepared by Roy F. Weston Inc. May 1993.

(9) U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). *Feasibility Study for the Explosives Washout Lagoons (Site 4) Soils Operable Unit. Umatilla Depot Activity (UMDA) Hermiston, Oregon.* Final Report. Report No. CETHA-BC-CR-92017. Prepared by CH2M Hill and Morrison Knudsen Environmental Services. April 1992.

(10) U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). *Evaluation of Composting Implementation.* Final Report. Prepared by Remediation Technologies Inc. August 1990.

(11) Wilder Construction Company. *Phase I, Contaminated Soil Remediation, Explosives Washout Lagoons, Umatilla, Oregon.* Contract No. DACA67-93-B-0088. Final Remedial Action Management Plan (RAMP). June 1994.

Report Preparation Information

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