MINIMIZING SOIL REMEDIATION VOLUME THROUGH SPECIFICATION OF EXCAVATION AND MATERIALS HANDLING PROCEDURES

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ABSTRACT

The technologies currently available for treating soils contaminated with the explosives 2,4,6-trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazene (RDX) are both limited and expensive. Therefore, an important consideration in soils remediation is the preparation of construction specifications and contract drawings which limit the volume of soil that will be required to undergo treatment. Construction specifications and contract drawings were developed for the Contaminated Soil Remediation of the Explosives Washout Lagoons at Umatilla Depot Activity (UMDA) with the following primary objectives: (1) limit the volume of soil excavated from the Explosives Washout Lagoons and Explosives Washout Plant Areas, (2) minimize materials handling, and (3) reduce the excavated volume of soil which will undergo treatment.

Excavation procedures were developed to provide the Contracting Officer a high degree of control over each layer of soil that will be excavated during construction. In developing the excavation procedures, both physical and chemical soils data generated during remedial investigations and feasibility studies at the site were reviewed in detail. The following restrictions were placed on the excavation: areas (grids) to be excavated were designated on the contract drawings; the excavation depths for each layer in each grid were designated and cross-sections of these layers were provided on the contract drawings; the limit of excavation for each grid will be based on the results of field analyses for TNT and RDX by EPA Methods 8515 and 8510, respectively, of composite soil samples collected at five pre-designated sampling locations for each grid; and once the field analytical results show that excavation limits for TNT and RDX of 30 mg/kg or less are attained, samples will be submitted for laboratory confirmational analyses. The specifications were developed so that the Contracting Officer is the determinant in all critical decision points of the excavation. The Contracting Officer will determine the preliminary limit of excavation based on review of the field analytical data submitted by the Contractor. Submittal of soil for confirmational analysis by EPA Method 8330 will be conducted by the Contractor under the direction of the Contracting Officer. The Contracting Officer will review the confirmational data and make the final ruling on whether excavation is complete. These highly controlled excavation procedures have been referred to as "surgical excavation." Because these procedures are restrictive, minimizing Contractor down-time was given particular consideration. The specifications were designed to allow the Contractor to proceed in excavation in adjacent grids, under controlled conditions, while awaiting the results of the chemical analyses.

The next step of the excavation and materials handling procedures focussed on reducing the volume of soil through particle-size fractionation. The materials handling procedure was developed based on review of treatability work conducted on soil excavated from the Explosives Washout Lagoons for soil washing. Screening will be conducted to separate material: 1) less than 1/4-inch, 2) between 1/4-inch and 2-inches, and 3) greater than 2-inches in diameter. Samples of the two coarser grain-size fractions will be analyzed for TNT and RDX by EPA Method 8330 to determine whether treatment of the coarse grain-size fraction is necessary. If the concentration of either TNT or RDX is greater than 30 mg/kg, the material will then be stored for treatment.

INTRODUCTION

In recent years the focus of remediation on hazardous waste sites has changed from investigation to restoration. In the initial years of Superfund, emphasis was placed on site discovery and understanding the nature and extent of contamination and its fate and transport in the environment.

With this focus, the primary portion of funding was expended trying to define the problem, rather than focusing on how to fix the problem and implementing remediation. Especially in the case of soil contamination, in which there is typically a high degree of variability in the concentration of chemicals detected in soil (even from samples which are collected adjacent to each other), an inordinate number of samples would have to be collected in order to specify to a Contractor the area and depth of soil which requires remediation to a reasonable degree of certainty. During the investigation phase, site characterization should be conducted only to the extent necessary to: (a) define the chemicals and areas of concern, (b) provide a preliminary volume estimate of contaminated soil, (c) enable an engineering analysis for the development, evaluation, and selection of remediation alternatives for the site, and (d) provide information to the remediation designer and contractor. The actual extent of remediation should be determined during construction.

Contract drawings and specifications for soil remediation of the Explosives Washout Plant at UMDA were developed with the intent that the extent of excavation for soil remediation would be determined by field screening and laboratory chemical analyses of soil samples collected during construction. Procedures were developed to minimize overexcavation of soil with contaminant concentrations below the established cleanup level. In addition, materials handling procedures, primarily using particle-size fractionation of the soil, were developed to minimize the volume of excavated soil requiring treatment.

BACKGROUND

Umatilla Depot Activity (UMDA) is a 19,728-acre military facility located in northeastern Oregon, approximately five miles west of Hermiston, Oregon. The facility was established as an Army ordnance depot in 1941 for the purpose of storing and handling conventional munitions.

The UMDA operated an onsite explosives washout plant from the early 1950s to 1965. The plant processed munitions to remove and recover explosives using a pressurized hot water system. The principle explosives processed included 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazene (commonly referred to as Royal Demolitions Explosive or RDX), octahydro-1,3,5,7-tetrazocine (commonly referred to as High Melting Explosives or HMX), and 2,4,6-tetranitro-N-methylaniline (tetryl).

Operation of the plant included flushing and draining the explosives washout system on a weekly basis. This operation produced approximately 150,000 gallons of explosive-containing effluent per week. The effluent was discharged along an open steel overflow trough, with a sump located approximately midway between the plant and two, unlined infiltration lagoons (Figure 1). Effluent was directed from the trough into the lagoons by a moveable section of the trough. The solution in the lagoons infiltrated into the ground or evaporated. Sludge that accumulated in the lagoons and in the in-line concrete settling sump located along the trough was periodically removed (1).

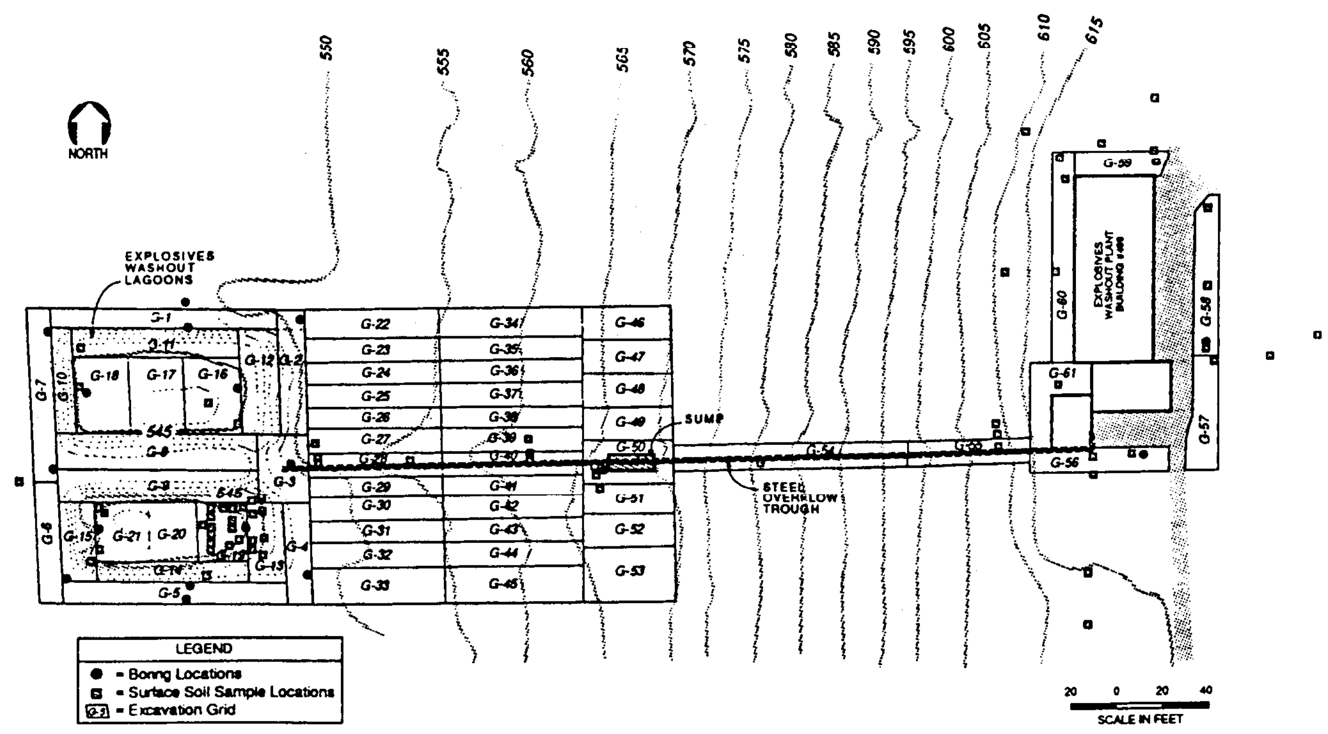

FIGURE 1: EXCAVATION GRID LAYOUT

The north and south lagoons are approximately 54 feet by 98 feet and 41 feet by 97 feet, respectively. They are 5 feet deep. The lagoons are separated by a 15-foot wide gravel berm. The lagoons were constructed of native sandy-gravelly soil. The depth to groundwater from the bottom of the lagoons generally varies from 45 to 50 feet.

Summary of Chemical Impact to Soil

Environmental investigations of this area of the UMDA concluded that discharge to the lagoons had caused contamination of the underlying soil and alluvial aquifer. In addition, soils in the vicinity of the plant and along the trough have been chemically impacted by facility operations.

The nature and extent of soil contamination at the site were characterized by 88 surface soil samples and 19 borings. Of those samples collected, 50 surface soil samples and soil samples from 14 borings were collected from the Explosives Washout Lagoons. Sample locations are shown on Figure 1 (some of the sample locations were either only descriptive in general terms or missing, and therefore, not shown on the figure).

The results of the investigation indicated that contamination by TNT, RDX, HMX, trinitrobenzene (TNB), and 2,4-dinitrotoluene (2,4-DNT) is present throughout the vertical extent of the unsaturated soil column directly beneath the lagoons. Other nitroaromatic explosive compounds were not frequently detected, and when detected, were measured at concentrations less than 5 mg/kg. Concentrations typically ranged from 2 to 2,000 mg/kg for RDX and 2 to 90,000 mg/kg for TNT to a soil depth of 4 feet in the lagoons. TNT concentrations exceeding 2,000 mg/kg have been observed in the top 18 inches of soil. The maximum TNT concentration of 90,000 mg/kg (9 percent) was detected in the top one inch of soil in the south lagoon. TNT concentrations greater than 10 percent can propagate an explosion if detonated. Concentrations of 1,100 mg/kg TNT and 66 mg/kg RDX to a depth of 8 feet were detected in the area of the Explosives Washout Lagoon where the trough was located. Soil with TNT and RDX concentrations greater than 30 mg/kg have been detected at various depths between 15 and 40 feet beneath the lagoons.

Analytical results for soil sampling conducted around the Explosives Washout Plant and adjacent to the discharge trough indicate that these areas are in general chemically impacted to a lesser extent than the Explosives Washout Lagoons. TNT was detected in 18 samples, and ranged in concentration from 1 to 9,900 mg/kg. RDX was detected in 28 samples, ranging in concentration from 1 to 1,600 mg/kg. The highest detections of TNT and RDX for this area of the site were measured in surface samples collected from the southeast area of the Explosives Washout Plant.

Scope of Work

The UMDA currently operates as a munitions storage facility. The facility is being realigned under the Department of Defense Base Realignment and Closure program. Under this program, it is probable that the Army will eventually vacate the site. Ownership could then be relinquished to another governmental agency or to private interests.

The Record of Decision (ROD) was issued in September 1992 for the UMDA Explosives Washout Lagoons Soil Operable Unit (2). This operable unit addresses the contaminated soils in the vicinity of the Explosives Washout Lagoons, along the steel overflow trough, and at the Explosives Washout Plant. The selected remedy includes the following components:

- Excavation of soils having TNT or RDX concentrations greater than 30 mg/kg each.
- Onsite biological treatment of excavated soils by composting to TNT and RDX concentrations of 30 mg/kg each.
- Replacement of composted soils into the excavation, covering the area with two feet of clean soil, and revegetation.

Woodward-Clyde was awarded the Remedial Design for the Contaminated Soil Remediation at the Explosives Washout Lagoons under a U.S. Army Corps of Engineers, Seattle District, Indefinite Delivery Contract in January 1993. The remedial design was conducted in a phased approach. The Phase I Design primarily included the excavation and stockpiling of the contaminated soils, and the Phase II Design included treatment of the soils. The phased approach was chosen to:

1. Allow for competitive bidding and award to the lowest responsive bidder for the non-specialized services required (i.e., excavation, screening, and storage of contaminated soil).
2. Expedite the remediation schedule by starting Phase I construction activities before the Phase II Contractor is selected.

During the Phase I Design, it was obvious that minimizing the volume of soil requiring treatment would reduce the cost of remediation. Therefore, one of the primary objectives of the Phase I Design was to minimize soil remediation volume by producing construction specifications and contract drawings which would restrict the Contractor to very controlled excavation and materials handling procedures. The excavation procedures developed for the Phase I Design has been coined by the project team "surgical excavation." The basis of design are described in the following sections.

EXCAVATION PROCEDURES

The excavation procedures developed for the Phase I Design included the following components:

1. Developing a grid layout by which the excavation would proceed.
2. Determining the depth of excavation depths for each layer of soil in each grid.
3. Developing a sequence for excavation of the grid.
4. Specifying field sampling and analysis procedures.
5. Specifying laboratory confirmational sampling and analysis procedures.

Each of these aspects of the design are described in the following sections.

Grid Layout

The layout of the areas (or grids) from which the Contractor will excavate explosives-contaminated soil for the Phase I contaminated soil remediation was developed using the following considerations:

- The areal extent of contamination is defined by results of chemical analysis performed during the remedial investigation.
- Potential contaminated areas of concern are based on available historical information on the facility operations which were not sufficiently characterized during the remedial investigation.
- Topographic features of the site (i.e., the lowest depressions in the lagoons are likely to have higher concentrations of explosives due to gravity flow and concentration by evaporation).
- Allowances for sufficient space in which excavation equipment could maneuver without undue constraints on type of equipment used for excavation.
- An evaluation of treatment costs in relation to volume of soil excavated (i.e., a trade-off between added costs due to a highly controlled excavation versus potentially treating excavated soils which contain explosives at concentrations below the required excavation/cleanup levels).

The cost evaluation was conducted using estimated treatment costs from the Feasibility Study. The Feasibility Study estimated unit cost for treatment of soil by composting was $288 per ton (capital, operation, and maintenance costs) or $460 per cubic yard, assuming 1.6 tons per cubic yard of soil (3). Therefore the estimated cost of treating 20 cubic yards of soil was $9,200. Typical costs of excavating sandy soil is $10 per cubic yard. The excavation costs for using a restricted excavation procedure was estimated to be $20 per cubic yard of soil and $100 for field analytical cost per excavation layer of soil. Therefore, the incremental costs for restricted excavation was estimated at $300 per 20 cubic yards of soil (or about $15 per cubic yard of soil). This accounts for only 3% of the estimated treatment costs. Therefore, the added cost for restricted excavation were considered negligible to the total remediation costs.

The typical grid size of approximately 540 square feet was based on an excavation of 20 cubic yards of soil per layer using a 1-foot excavation depth. As a result of a cost evaluation and in consideration of the factors previously described, 61 grids subdividing an area of less than one acre were identified on the contract drawings. These grids, as identified by G-#, are shown on Figure 1. The grid designations are as follows:

- Boundary surrounding the lagoons: grids G-1 through G-7; the area designated by grid G-3 was chemically impacted by the trough.
- Central berm: grids G-8 and G-9.
- Lagoon sidewalls: grids G-10 through G-15.
- Bottom of lagoon: grids G-16 through G-21.
- Steel overflow trough area: grids G-22 through G-55; the area designated by grid G-50 was chemically impacted by the sump.
- Area surrounding the Explosives Washout Plant: grids G-56 through G-61.

The size of these grids range in area from 486 to 1392 square feet. The average size of the grids is 617 square feet.

Excavation Depths

All available and relevant chemical data were compiled to estimate the vertical and horizontal extent of excavation of contaminated soil in the Explosives Washout Lagoons, steel overflow trough, and Explosives Washout Plant areas. Chemical profiles were developed to determine the areas (i.e., the grids as identified in the previous section) and depths at which 30 mg/kg TNT or RDX was exceeded.

These chemical profiles were used to compile the following volume estimates:

1. Minimum extent of excavation.
2. Estimated probable extent of excavation.
3. Maximum additional excavation to the extent practicable.

The minimum extent of excavation represents the minimum volume of soil that will be excavated. This division was supported by a relatively high degree of chemical characterization of soil at shallow depths which provided a high degree of certainty as to the extent of contamination.

The estimated probable extent of excavation required making a judgement on the extent of contamination where analytical information was not available. This estimate used information regarding historical operations of the facility.

The maximum practicable extent of excavation was based on consideration of environmental benefits versus cost of remediation and was designated through negotiations with the regulators. The estimation of the practicable extent of excavation was primarily focused to limit the excavation in the Explosives Washout Lagoons area. In this area, contamination had been detected to the groundwater table; therefore, it is possible (although not probable) that TNT or RDX may be detected at concentrations which exceed 30 mg/kg at substantial depths. The 30 mg/kg remediation limit for TNT and RDX was based on a risk assessment from a human exposure scenario (3). The risk that remains at deeper depths is not from direct contact with the soils, but from secondary pathways of exposure (i.e., as a source of contamination to groundwater). The majority of the mass of contamination will be removed from the minimum excavation limits. In addition, the Feasibility Study considered excavation of soil to groundwater (i.e., about 45 feet). The selected remedy presumed that cleanup to the designated cleanup levels would include excavation of only "shallow" soil, which was estimated to be 10 feet. Therefore, the basis for the maximum excavation limits was designated at 15 feet below the natural ground surface (for the lagoon area, the natural ground surface is defined as the elevation of the perimeter of the lagoons). At this depth, human exposure from direct contact with soils is highly unlikely from any future land development activities. It is important to establish maximum limits of excavation prior to construction to provide the Contractor bidding information.

The estimated volume of contaminated soil is 949; 2,900; and 6,300 in-place cubic yards for the minimum, probable, and maximum excavations, respectively.

The minimum, probable, and maximum excavations were provided to the Contractor on the contract drawings. Table 1 is a re-creation of the table shown in the contract drawings for the Explosives Washout Lagoons. Along with this table. detailed cross-sections of the excavation for the Explosives Washout Lagoons, steel overflow trough, and the Explosives Washout Plant were provided on the contract drawings. These sections showed the minimum and potential maximum extent of excavation for each layer of soil in each grid and the excavation sequence. An example of one of the cross-sections of the North Explosive Washout Lagoon is shown on Figure 2.

Table 1. Estimated Depth of Excavation

	Dimensions			Depth of Excavation (feet bgs)		
Grid No.	N-S (feet)	E-W (feet)	Area (sq ft)	Mini-mum	Prob-able	Maxi-mum
Washout Lagoon Area						
G-1	9	98	882	0.5	1	2
G-2	54	9	486	0.5	1	2
G-3	31	20	620	1	8	15
G-4	43	10	430	0.5	1	2
G-5	9	97	873	0.5	1	2
G-6	52	10	520	0.5	1	2
G-7	76	10	760	0.5	2	4
G-8	16	87	1392	4	6	15
G-9	15	87	1305	4	6	15
G-10	45	9	405	1	5	15
G-11	12	72	864	1	5	15
G-12	45	17	765	1	6	15
G-13	34	16	544	1	4.5	15
G-14	9	65	585	1	5	15
G-15	34	16	544	1	5	15
G-16	33	24	792	2	8	10
G-17	33	24	792	2	10	10
G-18	33	24	792	2	6	11
G-19	25	21	525	2	4	11
G-20	25	21	525	2	8	10
G-21	25	23	575	2	10	10

Excavation Sequence

The excavation sequence was developed to minimize the amount of soil to be excavated and minimize subsequent costs from additional unnecessary materials handling and treatment. The specifications require the Contractor to implement an excavation procedure which will limit excavation of contaminated soils beyond the specified layer depth shown on the contract drawings.

Strata of explosives approximately 1/16-inch to 1/4-inch in thickness and particles of explosives up to 1/4-inch in diameter had been observed in the central berm, sidewalls, and bottom of the Explosives Washout Lagoons to a depth of approximately 1-foot to 1.5-feet below the ground surface. Because this material presents a potential safety hazard to workers, the first layer of grids G-8 through G-21, shown as the minimum depth of excavation, are required to be excavated as one unit. The procedure

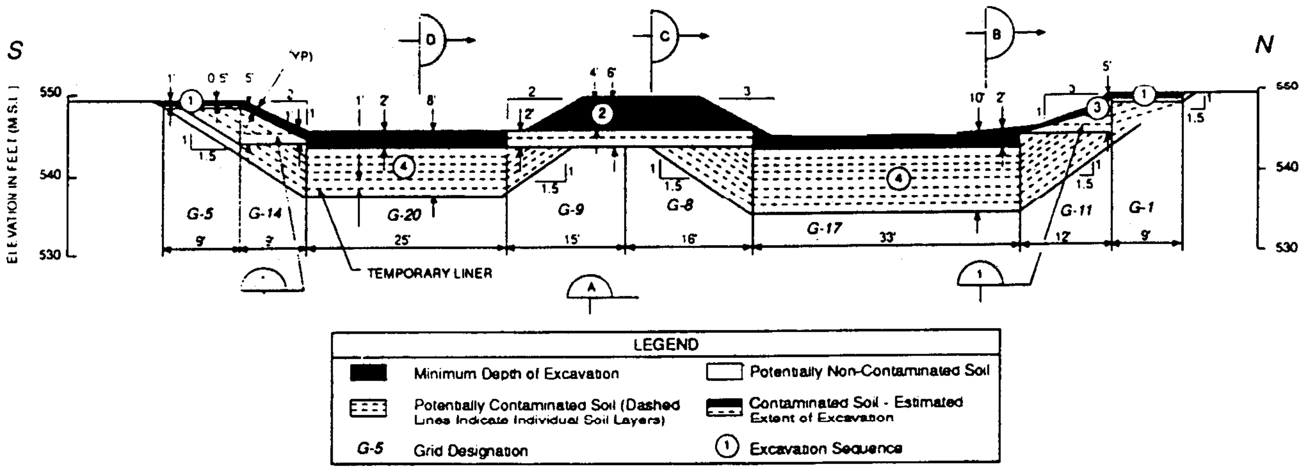

FIGURE 2: EXCAVATION SECTION

includes pushing the first one-foot of grids G-10 through G-15 (the lagoon sidewalls) down into the bottom of the lagoon. This material is then required to be mixed with the top two feet of soil in the bottom of the lagoon. This first division of soil will be stored separately from the other excavated soils.

The excavation will proceed in the following sequence:

1. Perimeter of the lagoons and grids in the trough overflow area which are adjacent to the lagoons (note that the steel overflow trough will be removed before the excavation proceeds in this area).

2. Central berm area of the lagoons.

3. Sidewalls of the lagoons.

4. Bottom of the lagoons.

5. Lower overflow trough area.

6. Upper overflow trough area.

7. Explosives Washout Plant area.

Field Sampling and Analysis

After the minimum extent of excavation has been completed, field sampling and analysis of the soil for TNT and RDX will be conducted to determine whether the subsequent exposed layers of soil require excavation. The field analytical methods for TNT and RDX (EPA Method 8515 and 8510, respectively) are colorimetric methods which use standard reagents and a spectrophotometer.

The soil samples will be collected by the Contractor from the undisturbed soil below the depth disturbed by excavation. Samples will be collected for each grid from five pre-determined sample locations within the respective grids and composited for analysis. The sampling locations were pre-determined to remove sampling bias from the field sampler.

The objective of selecting the sample locations was to obtain a sample which is representative of the concentration of explosive compounds within each grid. All the grids, with the exception of grids G-57 and G-61, are nearly rectangular. The grids were divided into five equal subareas. The five subareas include four corner areas (northwest, southwest, northeast, and southeast) and a central area. Subsamples are located within the midpoint of the sampling subareas. Figure 3 shows a typical layout of the sample locations for each grid as provided in the contract drawings. Also provided in the contract drawing are tables which show the distances from the boundary of each of the grids for stationing the sample locations. An example is provided as Table 2.

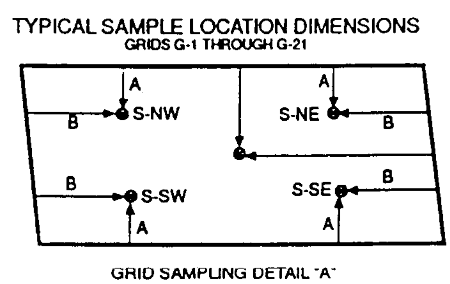

FIGURE 3: GRID SAMPLING DETAIL

The five pre-determined sampling locations for grids G-57 and G-61 were selected considering the configuration of the grid and with the objective of making the subareas equal, to the extent practicable.

Table 2. Grid Sampling Locations

Grid Number	A (feet)	B (feet)	C (feet)	D (feet)
G-1	2.25	19.6	4.5	49
G-2	13.5	1.8	27	4.5
G-3	7.75	4	15.5	10
G-4	10.75	2	21.5	5
G-5	2.25	19.4	4.5	48.5
G-6	13	2	26	5
G-7	19	2	38	5
G-8	4	17.4	8	43.5
G-9	3.75	17.4	7.5	43.5
G-10	11.25	1.8	22.5	4.5
6-11	3	14.4	6	36
G-12	11.25	3.4	22.5	8.5
6-13	8.5	3.2	17	8
G-14	2.25	1.3	4.5	32.5
G-15	8.5	3.2	17	8
G-16	8.25	4.8	16.5	12
G-17	8.25	4.8	16.5	12
G-18	8.25	4.8	16.5	12
G-19	6.25	4.2	12.5	10.5
G-20	6.25	4.2	12.5	10.5
G-21	6.25	4.6	12.5	10.5

Excavation will continue in layers in accordance with the depths shown on the contract drawings until the concentrations of TNT and RDX are shown by the Contractor and agreed upon by the Contracting Officer to be equal to or less than 30 mg/kg each by review of the analytical results of the field analyses conducted by the Contractor. Positive interferences in the field analysis for TNT are expected due to other nitroaromatic explosive compounds detected in the soil at the lagoons. Therefore, the actual concentration of TNT is expected to be less than 30 mg/kg when field analysis indicates that the TNT-class compounds are less than 200 mg/kg.

To allow the Contractor flexibility and limit construction down-time, the Contractor may start excavation in the adjacent grids after submitting confirmational samples to the laboratory. The Contractor is not permitted to excavate any layer beyond the estimated depth of excavation shown on the contract drawings until the results of the field or laboratory confirmational analyses have been evaluated by the Contracting Officer, and the Contractor has received written authorization to excavate the next layer of soil (see discussion below on confirmational sampling and analysis). No over-excavation of a potentially non-contaminated grid will be allowed until receipt of the confirmational results. After the soil in a grid is confirmed to meet the cleanup criteria, any overexcavation in that grid will be classified as non-contaminated soil and will be stockpiled separately from contaminated soil.

Confirmational Sampling and Analysis

When directed by the Contracting Officer, the Contractor is required to obtain representative composite samples for confirmational analysis. The composite samples will be collected from the sampling stations identified for the field sampling and analysis activity. Confirmational analysis will be conducted using laboratory EPA Method 8330 (a high performance liquid chromatographic method).

Because of the low likelihood of contamination in the grids located in the lower overflow trough area (excluding the grids beneath the overflow trough), confirmational samples will not be collected for those grids given the following conditions:

1. No excavation occurs
2. Field analysis shows concentrations of TNT and RDX less than 10 mg/kg.

MATERIALS HANDLING PROCEDURES

Reduction of the amount of contaminated soil requiring treatment by windrow composting may be accomplished by relatively simple physical and/or physicochemical methods:

1. Particle-size fractionation of soil by dry-screening the contaminated soil.
2. Aqueous-phase soil washing of the gravel.

It is possible to utilize these methods separately or in combination.

Particle-size fractionation of soil takes advantage of the chemical partitioning typically observed in soils. Because the surface area of gravel grain-size soils is low compared to the surface area of fine grain-size soils, there is typically a lesser mass of contamination associated with the larger-grain soils. Also, the sorptive properties are higher for silts and clay than sands and gravels; this contributes to a higher partitioning of the contaminants onto the finer grain-sized soils. Therefore, separation of the coarser grain-size soil particles from the finer grain-size particles may achieve an effective reduction of the volume of contaminated soil requiring treatment.

It is possible that particle-size fractionation alone may not adequately reduce contaminant concentrations in the coarser grain-size soil (i.e., gravel-size and greater). This may be due to the adherence of more highly contaminated, finer grain-size soil to the surfaces of the coarse grain-size fraction and/or entrainment of the chemical into the coarse grain-size fraction. Therefore aqueous-phase soil washing of the coarse grain-size fraction may be effective at further reducing the chemical concentration of contaminants in soil.

Treatability Study Evaluation

To evaluate the effectiveness of soil washing, treatability studies were conducted using soil from the Explosives Washout Lagoons (4). The soil tested was material generated from the soil screening process used during the composting study. This material primarily consisted of gravel-size particles with minor amounts (< 2% by weight) of sand and silt. The cobble size fractions were not included in the study. The results of the treatability studies were evaluated to determine the feasibility of treating the coarse grain-size fraction by aqueous-phase soil washing.

Two soil washing methods were evaluated by Roy F. Weston, Inc.:

1. Screen washing.

2. Tumbler washing.

The screen washing test was designed to simulate a full-scale vibrating screen equipped with a pressurized water spray. The screen washing evaluated three contact times (5, 10, and 15 minutes) at a spray application rate of 20 gallons per minute (gpm) and two spray temperatures (70°F and 140°F).

The tumbler washing simulated a submerged, agitated washing process. Two contact times (10 minutes and 30 minutes) were evaluated, each using six sequential wash stages. At each subsequent wash stage, the soil was returned to the tumbler and clean water was added. The target water-to-soil volume ratio was 100 gallons of water per cubic yard of soil (4).

The following general conclusions were made from the study:

1. In both the screen and tumbler washing tests, the sand-size fractions contained higher concentrations of explosives than the gravel-size fractions.

2. Greater reductions in concentration of TNT and RDX were attained by the tumbler washing method than by the screen washing method.

3. The effectiveness of removal of explosives from the gravel grain-size soil by tumbler washing was likely reduced because the fine grain-size fraction was not removed before conducting subsequent washings.

Based on these results, the feasibility of the tumbler soil washing method was evaluated for full-scale soil washing at the UMDA.

Woodward-Clyde has conducted past studies for other sizes that indicated the removal rate of chemicals by a multi-stage batch soil washing process displays a logarithmic decrease. The chemical results of the soil for the tumbler washing test were graphed on normal and log-normal scales for the 10-minute and 30-minute wash times. This logarithmic removal rate was displayed by the soil samples tested for RDX for wash stages 1 though 6 and for TNT for wash stages 1 through 3. As previously discussed, the fine grain-size particulates were not removed from the process in each wash stage and likely resulted in a loss of efficiency of removing the explosives from the fine grain-size soil particles. The data were extrapolated using the log-normal relationship from the initial chemical results of the soil and the chemical results from the third wash stage. This evaluation indicated that four wash stages would be required to reduce TNT and RDX to below cleanup levels.

Considering the relatively low volume of gravel expected from the excavation (500 to 1,100 cubic yards), it is highly unlikely that an aqueous-phase soil washing system which requires four wash stages would be economically feasible. This system would require a series of washing, screening, and dewatering equipment. In addition, there would be costs incurred from storing an estimated 50,000 to 100,000 gallons of water and for disposal of excess water which may not be utilized during composting (i.e., a four stage-counter current soil washing system was estimated to generate 100 gallons per cubic yard of soil which is in excess of the average water utilization rate of 70 gallons per cubic yard based on the results of composting treatability testing study (5). Therefore, aqueous-phase soil washing was not recommended as part of the remedial activities.

The material tested was composed of highly contaminated, near-surface materials that are not representative of soils which may be encountered at deeper depths. Chemical analysis of gravel-size particles at deeper depths has not been conducted at the site. However, as shown by the chemical analyses from soil borings in the lagoon, it is expected that the concentration of explosives of the gravel grain-size particles will be less than the concentrations of explosives of the gravel grain-size particles near the surface. Therefore, it is possible that "dry-screening" alone may effectively reduce the volume of soil requiring treatment. Dry-screening will be conducted at the natural moisture content.

Design of Soil Processing Procedures

Dry-screening of the soil serves two purposes:

1. Potential reduction of contaminated soil requiring treatment by windrow composting.

2. Preparation of soil for composting to reduce the safety hazard. (The gravel-size particles and larger size materials may damage windrow composting equipment and may behave as projectiles causing a safety hazard.)

The specification of the soil processing procedure included the following components:

- Contaminated soil will be dry-screened at the excavation site to separate material less than 1/4-inch, between 1/4-inch and 2-inches, and greater than 2-inches in diameter. The soil from the minimum extent of excavation will not be screened because of the potential elevated explosion hazard from particles and thin sheet of explosives observed in this material.

- Activities will be performed to keep the moisture content to a minimum since moisture in the soil will decrease the efficiency and effectiveness of separation of the soil fractions. Drying of the soils will not be required to reduce moisture content and enhance separation effectiveness.

- If ineffective fractionation of the soil particles is observed, re-screening of the coarse grain-size fraction may be required by the Contracting Officer.

- Screening will be conducted in an enclosed system to reduce dust generation.

- Material less than 1/4-inch, between 1/4-inch and 2-inches, and greater than 2 inches in diameter will be stockpiled separately. The two coarser grain-size fractions will be stockpiled in volumes of approximately 20 cubic yards.

Sampling and Analysis

A grab sample from each 20 cubic yard stockpile will be collected and submitted to the laboratory for analysis by EPA Method 8330. A composite sample will not be taken because of the infeasibility of compositing gravel grain-size and greater particles. The samples will be crushed prior to extraction for analysis. Because only excavation of soils which have been determined contaminated at concentrations greater than the cleanup level will be conducted, the fine grain-size fraction (< 1/4-inch in diameter) will be presumed contaminated. Therefore, chemical analysis of this fraction of soil will not be conducted.

Storage Handling Procedures

The fine grain-size fraction of cleanup level, soil and the stockpiles of the two coarse grain-sized fractions of screened soil which do not meet cleanup criteria (< 30 mg/kg TNT and RDX each) will be transported to the storage facility for treatment by windrow composting during the Phase II remediation activities. Contaminated soil greater than 2- inches in diameter will be stockpiled in the storage facility separately from other contaminated soil. This procedure was specified because this coarse grain-size soil may cause additional wear on the windrow turner and cause the Phase II Contractor additional maintenance costs which the Contractor may find unacceptable. Stockpiling this material separately will provide the Phase II Contractor the opportunity to conduct further processing of the material (i.e., crushing before treating).

SUMMARY

Minimizing soil remediation volume was given particular consideration in the Phase I Design of the Contaminated Soil Remediation of the Explosives Washout Lagoons at UMDA because of the relatively high cost of treatment estimated by the Feasibility Study ($460 per cubic yard). The contract drawings and specifications were developed with the primary objectives of:

1. Limiting the volume of soil excavated from the Explosives Washout Lagoons, steel overflow trough, and Explosives Washout Plant areas.

2. Minimizing materials handling.

3. Reducing the excavated volume which will undergo treatment.

4. Provide field screening methods which allow the Contractor to continue while waiting for confirmational analysis of cleanup of previously excavated grids.

The excavation procedures developed in the specification provide the Contracting Officer with a high degree of control over each layer of soil that will be excavated during the Phase I Remediation and the flexibility to the Contractor in excavating adjacent grids to minimize construction down-time.

The Contractor is constrained to conduct the excavation within designated grids; excavated to a specified depth for each layer of soil within each grid; and rely on the results of field analyses and the approval of the Contracting Officer before proceeding with excavation. In addition, the Contractor is constrained by specified sampling and analysis procedures.

Further reduction in the volume of contaminated soil will be achieved by particle-size fractionation of the soil through dry-screening. The contaminated soil will be separated into the following particle-size fractions: less than 1/4-inch, 1/4-inch to 2-inches, and greater than 2-inches in diameter. The two coarser grain-size fractions will be stockpiled in 20 cubic yard stockpiles from which a grab sample will be collected and submitted for chemical analyses. The stockpiles of soil for chemical results that show concentrations greater than the cleanup levels will be stored for treatment. The fine grain-size fraction (< 1/4-inch in diameter) will be stored for treatment without conducting further sampling and analysis.

REFERENCES

1. Dames and Moore, Inc., 1992, Remedial Investigation Report for the Umatilla Depot Activity, Hermiston, Oregon. Prepared for the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-3C-CR-72054, Contract No. DAAA15-88-D-0008, Delivery Order No. 3, August 1992.

2. U.S. Army Installation Restoration Program, Record of Decision, Umatilla Depot Activity Explosives Washout Lagoons Soils Operable Unit, September 1992.

3. Morrison Knudsen Environmental Services and CH2M Hill, Final Report, Explosives Washout Lagoons Soils Operable Unit Supplemental Investigation, Technical and Environmental Management Support of Installation Restoration, Technology Development Program, Umatilla Depot Activity, Hermiston, Oregon, Prepared for the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-BC-CR-92016, Master Agreement No. 057970-A-D1, EMO Task Order No. 14213, April 1992.

4. Weston, Roy F., Draft Summary Report for Bench-Scale Test for Aqueous Washing of Lagoon Soil, Prepared for the U.S. Army Environmental Center, February 1993.

5. Weston, Roy F., Inc., 1993, Draft Report, Windrow Composting Demonstration for Explosives-Contaminated Soils at Umatilla Depot Activity, Hermiston, Oregon, Prepared for the U.S. Army Environmental Center, Report No. CETHA-TS-CR-93043, August 1993.