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Addendum for TNT Area A
TNT Areas A and C Focused Feasibility Study for Soil and Sediment
Former Plum Brook Ordnance Works
Sandusky, Ohio

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List of Acronyms

ADNT	aminodinitrotoluene
ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COC	chemical of concern
cy	cubic yard
°C	degrees Celsius
DNT	dinitrotoluene
EC_{50}	half maximal effective concentration
EDA	electron donor-acceptor
EHQ	environmental hazard quotient
FFS	focused feasibility study
FS	feasibility study
lb	pound
LDR	land disposal restriction
MDC	maximum detected concentration
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NAC	nitroaromatic compound
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	operation and maintenance
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PCB	polychlorinated biphenyl
RAB	Restoration Advisory Board
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RG	remedial goal
RI	remedial investigation
SLERA	screening-level ecological risk assessment
SOM	soil organic matter

List of Acronyms (Continued)

TAT	triaminotoluene
TCLP	toxicity characteristic leaching procedure
TDL	Technology Development Laboratory
TNB	trinitrobenzene
TNT	trinitrotoluene
TNTA	TNT Area A
TNTB	TNT Area B
TNTA	TNT Area C
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USERDC	U.S. Army Engineer Research and Development Center
VAAP	Volunteer Army Ammunition Plant

Executive Summary

This addendum is a supplement and partial revision to the final focused feasibility study (FFS) for Soil and Sediment at TNT Area A (TNTA) and TNT Area C located at the former Plum Brook Ordnance Works (PBOW) in Sandusky, Ohio. The U.S. Army Corps of Engineers contracted Shaw Environmental, Inc. to conduct this FFS addendum under Delivery Order DX02 of Contract Number W912DR-05-D-0026. This addendum was prepared for TNTA only; a separate addendum has been prepared for TNT Area C.

The purposes of this FFS addendum are as follows:

- Screen new remedial technologies that have been developed since the October 2003 FFS (sections in Chapter 3.0)
- Revise the technology screening to include recent treatability study results and new information about technologies that have been implemented in recent remedial actions at other areas of PBOW (sections in Chapter 3.0)
- Revise the development and detailed analysis of remedial alternatives (Chapter 4.0)
- Revise the cost tables (Chapter 4.0)
- Revise the comparative analysis of remedial alternatives (Chapter 5.0)
- Separate out the volumes and other site-specific information as it applies to TNTA only.

This information is presented as revised sections and associated tables of the FFS. As such, these sections and tables are numbered according to their placement in the FFS. Note also that within these revised sections, the term “this FFS” which appears in revised sections of Chapter 3.0, 4.0, and 5.0 should be understood as meaning “the revised sections to the FFS contained in this addendum.”

This addendum is not intended as a stand-alone document. Please refer to the FFS for background discussion on PBOW and TNTA, or information such as the nature and extent of contamination, the human health or ecological risk assessments, remedial action objectives, remedial goals, or the specific areas of contaminated soil that require remedial action at TNTA.

The following process options and technologies were revised or added to the technology screening and are presented in Chapter 3.0 of this report:

- Chemical stabilization (revised Section 3.3.4)
- Windrow composting (revised Section 3.3.6)
- Alkaline hydrolysis (new Section 3.3.7)

Five remedial alternatives were developed and evaluated in Chapter 4.0 of this report based on the revised technology screening. All volumes reported below in the description of the alternatives are based on in-place or consolidated soil and do not account for changes in volume due to excavation or treatment. The remedial costs account for changes in volumes associated with treatment. The six remedial alternatives are as follows:

- ***Alternative 1 – No Action.***

- ***Alternative 2 – Excavation, Windrow Composting, and Off-Site Disposal.*** Excavation of contaminated soil (17,157 cubic yards). Windrow composting of soil that is a hazardous waste due to elevated concentrations of 2,4-dinitrotoluene (DNT) only (3,319 cubic yards). Off-site treatment and disposal of soil that is a Resource Conservation and Recovery Act (RCRA) hazardous waste due to elevated concentrations of lead (1,339 cubic yards) at an approved hazardous waste treatment, storage, and disposal facility (TSDF); of this lead-contaminated material, approximately 40 percent (544 cubic yards) is estimated to be hazardous with respect to 2,4-DNT as well. Off-site treatment and/or disposal of polychlorinated biphenyl (PCB) remediation waste (119 cubic yards) at a Toxic Substances Control Act (TSCA)-approved TSDF; this material is also likely to be hazardous with respect to 2,4-DNT and a portion of it (approximately 60 cubic yards) is likely to be hazardous with respect to lead. Off-site disposal of composted soil (3,319 cubic yards) and the remaining untreated nonhazardous soil (12,380 cubic yards) in an approved solid waste landfill.

- ***Alternative 3 – Excavation and Off-Site Disposal.*** Excavation of contaminated soil (17,157 cubic yards). Disposal of nonhazardous soil (12,380 cubic yards) at an approved solid waste landfill. Off-site treatment and/or disposal of soil that is a RCRA hazardous waste due to elevated concentrations of 2,4-DNT and/or lead (4,658 cubic yards) at an approved hazardous waste TSDF. Off-site treatment and/or disposal of PCB remediation waste (119 cubic yards) at a TSCA approved TSDF; this material is also likely to be hazardous with respect to 2,4-DNT, and a portion of it is likely to be hazardous with respect to lead.

- ***Alternative 4 - Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal.*** Excavation of contaminated soil (17,157 cubic yards). Windrow composting of soil that is a hazardous waste due to elevated concentrations of 2,4-DNT (3,803 cubic yards). Ex situ chemical stabilization of soil that is a hazardous waste due to elevated concentrations of lead

(1,339 cubic yards). Off-site disposal of soil that is a PCB remediation waste due to elevated concentrations of PCBs (119 cubic yards) at a TSCA-approved TSDF; this PCB waste material is also likely to be hazardous with respect to 2,4-DNT, and a portion of it is likely to be hazardous with respect to lead. Off-site disposal of treated soil (4,658 cubic yards) and the untreated nonhazardous soil (12,380 cubic yards) in an approved solid waste landfill.

- ***Alternative 5 - Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, On-Site and Off-Site Disposal.*** Excavation of contaminated soil (17,157 cubic yards). Alkaline hydrolysis of soil that is a hazardous waste due to elevated concentrations of 2,4-DNT (3,803 cubic yards). Windrow composting of alkaline hydrolysis treated soil that is not acceptable for disposal back on site due to elevated concentrations of nitroaromatic COC (761 cubic yards). Ex situ chemical stabilization of soil that is a hazardous waste due to elevated concentrations of lead (1,339 cubic yards). On-site disposal of all alkaline hydrolysis treated and composted soil not treated for lead (3,319 cubic yards). Off-site disposal of soil that is a PCB remediation waste (119 cubic yards) at a TSCA approved TSDF; this PCB waste material is also likely to be hazardous with respect to 2,4-DNT, and a portion of it is likely to be hazardous with respect to lead.. Off-site disposal of lead stabilized soil (1,339 cubic yards) and the untreated nonhazardous soil (12,380 cubic yards) in an approved solid waste landfill.

The remedial alternatives were evaluated with respect to the seven threshold and balancing criteria specified by the Comprehensive Environmental Response, Compensation and Liability Act. The threshold criteria are protection of human health and the environment and compliance with applicable and relevant or appropriate requirements (ARAR). The balancing criteria are long-term effectiveness and permanence; reduction of toxicity, mobility and volume of contamination; short-term effectiveness; implementability and cost. The modifying criteria of state and community acceptance will be evaluated in a later decision document.

All of the alternatives, with the exception of Alternative 1, would meet the threshold criteria of protection of human health and the environment and compliance with ARARs. Alternatives 2 through 5 protect human health and the environment by removing soil from the site with concentrations of chemicals of concern (COC) above remedial goals (RG). This action would lower the human health and ecological risks associated with exposure to contaminated soil and protect groundwater resources by removing a potential source of groundwater contamination. Alternative 1 is not protective because soil with concentrations of COCs above RGs would be left in place.

With the exception of Alternative 1, the remaining alternatives are similar with respect to the evaluation of the balancing criteria, although there are some differences. Alternatives 2, 4, and 5 would employ treatment technologies that permanently and significantly reduce the toxicity, mobility or volume of hazardous substances. Under these alternatives, approximately 20 to 23 percent of the excavated soil would be treated. Most of the soil would be managed off site as a nonhazardous waste. Alternative 3 is different in that it would not involve any on-site treatment. Alternatives 2, 4, and 5 involve treatment technologies that biologically or chemically convert or transform COCs into less toxic constituents. Windrow composting, used in Alternatives 2, 4, and 5, has been implemented previously at PBOW and its effectiveness and limitations are well known. The alkaline hydrolysis technology used in Alternative 5 has shown recent promise in field tests at Volunteer Army Ammunition Plant and in a treatability study conducted by the Shaw Environmental, Inc. Technology Development Lab.

The total present value cost (including 30 percent contingency) for each of the five remedial alternatives is provided in the following table. Alternative 5 has the lowest remedial cost of the alternatives evaluated.

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
$0	$5.2 million	$4.7 million	$5.1 million	$4.0 million

2.0 Identification of Remedial Action Objectives at TNT Area A

2.4 Area and Volume Estimates of Contaminated Media

Identifying samples with COC concentrations above RGs is the first step in determining area and volume estimates of contaminated media. Concentration data for the media of concern at TNTA are shown in the shadowboxes on Figures 1-3 through 1-19 and 1-35. COC concentrations that exceed RGs are shaded on the figures. There exists some uncertainty concerning the extent of contamination at locations where circumambient data at concentrations below RGs are not available to completely delineate the boundaries of areas requiring remediation. At these locations the following rules were used to estimate remedial soil volumes:

- If the concentration of any COC at the lateral limit of the sampling data is greater than the RG but less than 10 times the RG, a 10-foot buffer was added to the lateral extent in that direction.
- If the concentration of any COC at the lateral limit of the sampling data is greater than 10 times the RG, a 30-foot buffer was added to the lateral extent in that direction.
- If the concentration of any COC at the vertical limit of the sampling data is greater than the RG but less than 10 times the RG, a 5-foot buffer was added to the vertical extent.
- If the concentration of any COC at the vertical limit of the sampling data is greater than 10 times the RG, the vertical extent was assumed to be the depth to the water table or bedrock, whichever is encountered first.
- If the concentration of lead on one side of a former building location is greater than the RG, the extent of contamination was assumed to be a 10-foot wide strip around the perimeter of the foundation. This 10-foot-wide strip was assumed from surface to a depth of 2 to 3 feet, except in areas where contamination was specifically encountered (to which the above rules were applied).

Areas of nitroaromatic and PAH contamination exceeding RGs are shown in red on the shadowbox figures, while lead and PCB contamination areas are shown in green. Note that Figure 1-35, depicting the contaminated soil in the Building 187 Area and referenced in revised Table 2-8 of this Addendum, was not included in the original Focused Feasibility Study (Shaw, 2003), but has since been generated based on a further internal review of the Focused Feasibility Study and is included as part of this Addendum. Also, Figure 1-17 has been revised to include additional remediation areas as shown on the attached copy of this figure; the attached Table 2-8 reflects this revision.

The estimated areas and volumes of contaminated soil potentially requiring remediation at each building at TNTA are shown on Table 2-8. The volume of contaminated soil at TNTA that may require remediation is estimated to be 17,157 cubic yards. Of this total, 4,777 cubic yards (28 percent) might be classified as a hazardous waste upon excavation because the soil contains 2,4-DNT or lead at concentrations that exceed the “20 times rule.” Section 2.5.1 describes how the “20 times rule” is used to classify contaminated soil for waste management. Additionally, another 119 cubic yards of soil with concentrations of total PCBs greater than 50 mg/kg would be classified as a PCB remediation waste upon excavation. Section 2.5.3 presents an overview of the Toxic Substances Control Act (TSCA) regulations that govern the management of PCB wastes.

It is important to note that there are significantly more analytical data for the nitroaromatic COCs than for lead or PCBs. As a result, there is a greater degree of uncertainty about the accuracy of the remedial volumes concerning these constituents.

3.3.4 Ex Situ Chemical Stabilization

3.3.4.1 Effectiveness

Chemical stabilization would likely be effective in immobilizing COCs in soil. Contaminated soil would be excavated and then mixed with stabilizing agents in a batch mixer or pug mill. Alternatively, some stabilization chemicals are sprayed on excavated soils and mixed with heavy equipment such as an excavator. Stabilization does not transform or remove the COCs from soil; it only hinders their environmental transport. Therefore, stabilization should be combined with other waste management options like off-site disposal in a nonhazardous waste landfill or capping of the stabilized soil. Off-site disposal may be more appropriate for stabilized soil at TNTA because the potential future land use at these sites could include residential development.

Ex situ chemical stabilization has been used previously at PBOW to immobilize lead in soil to pass the TCLP test and comply with land disposal restriction (LDR) alternative treatment standards for contaminated soil. However, the LDR alternative treatment standards for the nitroaromatic compounds 2,4-DNT and 2,6-DNT are measured as the total concentration of the constituent in the treated soil. Since stabilization does not destroy but only immobilizes contaminants, the stabilized soil may not comply with the LDR requirements for these constituents.

3.3.4.2 Implementability

This process is technically and administratively implementable at this site. The technology is mature, and equipment and personnel are readily available. Stabilized soil would likely be managed off site at a nonhazardous waste landfill.

3.3.4.3 Cost

The cost associated with ex situ stabilization is moderate and depends on the amount of excavated material requiring treatment, the amount of stabilizing agents required, and labor costs associated with the implementation.

3.3.4.4 Summary

The feasibility of this process option warrants further development in Chapter 4.0. The technology is appropriate for the treatment of lead but of questionable applicability for the treatment of DNTs, because it may not comply with LDR requirements.

3.3.6 Windrow Composting

3.3.6.1 Effectiveness

Windrow composting has been used in the past to treat a variety of organic contaminants, including nitroaromatic compounds, PAHs, and pesticides. In particular, windrow composting has been used within the past 10 years at several sites to effectively treat nitroaromatic-contaminated soil that has been impacted by the production or handling of TNT-based munitions. The technology has been implemented on a full-scale basis to treat TNT-contaminated soil at the Umatilla Depot in Hermiston, Oregon; the Naval Surface Warfare Center in Crane, Indiana; the Joliet Army Ammunition Plant in Elwood, Illinois; and the U.S. Naval Submarine Base in Bangor, Washington.

Composting can be distinguished from other types of bioremediation processes by the use of bulking agents, such as wood chips and straw, to increase the porosity of the soil. Manure, yard wastes, and wood processing wastes are often added to increase the amount of nutrients and readily degradable organic matter. Occasionally, other easily degradable carbon sources (e.g., molasses, acetate, glucose) are added to sustain microorganisms capable of degrading hazardous constituents. Inorganic fertilizers may be added to supplement available nutrients (USEPA, 1996).

Composting utilizes solid-, liquid- and gas-phase processes. The solid phase provides physical support for biofilm growth, a source of organic and inorganic nutrients, a sink for metabolic products, and thermal insulation. The liquid phase provides a matrix for the interchange of gases, nutrients, and metabolic products. The gas phase delivers oxygen and provides a sink for gaseous metabolic products, such as carbon dioxide and ammonia. The gas phase also serves as the primary heat sink, through evaporative cooling (USEPA, 1996).

The composting process is mediated by microbial populations that are classified as either mesophiles or thermophiles. Mesophilic microbes are those with an optimum temperature range of 25 to 40 degrees Celsius (^{o}C). Thermophiles have an optimum temperature range of 40 to 60^{o}C. Significant degradation of TNT has been reported within both temperature regimes, although slightly higher removals have been demonstrated under thermophilic conditions (Williams, et al., 1992).

Composting can biologically degrade organic contaminants via aerobic, anaerobic, or a combination of anaerobic and aerobic processes. Research on TNT degradation using composting has shown that a combined anaerobic/aerobic process is the most effective in detoxifying TNT-contaminated soil. The first step in the biological degradation of TNT involves the reduction of one of the three aromatic nitro groups to an amino group through nitroso and hydroxylamino intermediates. Figure 3-1 shows the specific case of the reduction of an aromatic nitro group during the fermentation of glucose (Daun, et al., 1998).

The sequential reduction of all three nitro groups, converting TNT to 2,4,6-triaminotoluene (TAT), can only be achieved under strict anaerobic conditions (Preuss, et al., 1993). Figure 3-2 depicts the transformation processes that are involved in degradation of TNT in an anaerobic/aerobic composting system (Bruns-Nagel, et al., 2000). Studies have shown that, in addition to the transformation of TNT to TAT, degradation of TNT may proceed through the condensation of amino-dinitrotoluenes to azoxy-tetranitrotoluenes (Achtnich, et al., 1999).

Significant mineralization of TNT via composting has not been demonstrated. This may be explained by the rareness of polynitroaromatic compounds in nature and the resistance of the highly oxidized trinitro-substituted aromatic ring to oxidative microbial attack (Rieger and Knackmuss, 1995). However, TNT degradation and transformation products can be stabilized through interaction with organic and inorganic soil components. The reduction of TNT in the presence of clay and humic substances has been shown to significantly increase the removal rate of nitroaromatics from soil. The TNT metabolites hydoxyamino-dinitrotoluenes and TAT strongly bind to clay minerals and humic substances (Daun, et al., 1998).

Three different types of interactions between TNT metabolites and soil are possible: physical sorption, sequestration, and covalent binding to soil organic matter. Only if TNT and its metabolites are bound through covalent linkages are they considered to be an integral part of the humus. When bound to humic materials in this manner, they are not considered to represent a potential future threat to the environment.

Composting studies using ^{14}C ring-labeled TNT have demonstrated significant binding of TNT transformation products to the humic substances (fulvic acid, humic acid, and humin) present in compost (Achtnich, et al., 1999; Drzyzga, et al., 1998; Bollag, et al., 2002). The studies reported that the immobilized (unextractable) fraction of the ^{14}C-TNT ranged from 82 to 84 percent. All three studies used a combination anaerobic/aerobic treatment approach.

The nature of the bonding mechanism between TNT metabolites and the humic materials in the compost has been investigated using ^{15}N-nuclear magnetic resonance spectroscopy of ^{15}N-labeled TNT (Achtnich, et al., 1999; Bruns-Nagel, et al., 2000; Bollag, et al., 2002). These studies found significant evidence of covalently bound ^{15}N. The Bruns-Nagel study found that the major portion (58 percent) of the ^{15}N was strongly bound to the humic fraction of the soil: 23 percent as heterocyclic structures, 15 percent covalently bonded, 15 percent as amino functional groups, and 2 percent as nitro functional groups.

The recent research has demonstrated that, after incorporation of the partially or fully reduced TNT into humic materials, the pollutant is practically indistinguishable from the soil organic matter. Further, it can be assumed that mineralization of the bound residue would occur at a rate similar to that of the mineralization of the natural humus. Even if some covalently bound molecules are subsequently released and become bioavailable, this process should not occur to an extent that would cause toxic effects (Bollag, et al., 2002).

Critical process parameters that impact the effectiveness of a composting process include porosity of the compost material, free air space, moisture content, particle size, temperature, carbon to nitrogen ratio, and pH. Bulking agents are typically added to the contaminated soil to increase the porosity of the composted material. Adequate porosity is needed to provide a conduit for air, water, and nutrients throughout the compost as well as to afford space for the growth of microbial communities. Compost bulk density typically ranges from 0.5 to 0.7 tons per cubic yard. Free air space is the portion of the porosity occupied by gas. Free air space is necessary for the maintenance of aerobic conditions within the compost. The gas/liquid ratio within the void space has a profound impact on the efficiency of the treatment process (Ro, et al., 1998).

Proper moisture content is required for nutrient transport and maintenance of the microbial communities. Constructing a compost shelter or covering the piles with a water-impermeable fabric will prevent infiltrating rainfall from creating excessive moisture conditions within the compost. Adequate moisture levels can be maintained by periodically adding water to the compost to replace losses from evaporation. The recommended moisture content for composting is between 40 and 65 percent of saturation (USACE, 2002). The moisture content of the compost should be checked 2 to 3 times per week during treatment. The water usage in windrow composting is typically 1 gallon per cubic yard of compost per day.

Particle size is important because it affects the surface area available for microbial activity as well as the pore space available for oxygen and nutrient transport. A particle size from 1.3 to 5 centimeters is reported in the scientific literature to be optimum for composting (Forster and Wase, 1987). USACE specifications recommend a particle size range of 2 to 10 centimeters (USACE, 2002). Larger particles reduce the surface area for microbial growth and may cause contaminants to become occluded such that they are not accessible for degradation. Wet clays, for example, can be difficult to mix with amendments, and lumping can result. Lumping limits oxygen transfer rates and contaminant availability, resulting in incomplete treatment. Excavated soil is typically screened prior to mixing with amendments to remove large objects, and a shredder or crusher may be used to reduce the size of oversize material to facilitate treatment. Excavated material is typically screened down to 2 inches. Material between 2 and 6 inches can be crushed for treatment. Material larger than 6 inches is normally stockpiled for disposal. TNT is sometimes found as nodules in contaminated soil that can be difficult to treat via composting. Researchers at the Idaho National Engineering and Environmental Laboratory have used acetone to dissolve chunks of TNT. The resulting acetone/TNT slurry is then added back to the compost pile. The acetone is biodegradable and provides an additional carbon source for microbial growth.

The type of temperature control employed depends on the composting process used. The compost temperature in static piles and in-vessel composting is controlled by adjusting airflow through the compost. Compost temperature during windrow composting is controlled by the frequency of windrow turning and by minimizing the impact of climatic effects through sheltering or covering the compost. USACE specifications recommend that the compost temperature be maintained between 54 ^{o}C and 60^{o}C for optimum treatment efficiency. Microbial activity is substantially reduced at temperatures above 71^{o}C. Temperature control is particularly important in locations such as northern Ohio, where the impact of winter temperatures on the effectiveness of composting operations must be considered. Low ambient temperatures will impact the process if the amendments and/or soil become frozen prior to blending. The initial self-heating phase may be longer or may not occur if one or more of the components is at or near freezing. This problem can be overcome by staging amendments in large piles during cold weather or by using engineering controls such as a small heated amendment staging area to heat a 1- to 2-day supply of amendments prior to mixing. The temperature of the windrows should be monitored on a daily basis.

Compost microorganisms require adequate levels of carbon sources and other nutrients, including nitrogen, phosphorus, sulfur, and other trace minerals. Among these, carbon and nitrogen are usually the limiting substrates. Optimal carbon to nitrogen (C/N) ratios for different composting materials are reported to range from 20:1 to 40:1 (USACE, 2002), although a lower C/N ratio was effectively used during the composting project at Naval Surface Warfare Center in Crane, Indiana. If the C/N ratio is too low, nitrogen will be lost as ammonia, which may reach toxic levels and raise the compost pH.

The optimum pH for composting has been reported in the scientific literature to range from 6.0 to 8.5 (Fitzpatrick, 1993). At higher pH, nitrogen will be lost as ammonia and essential elements such as calcium and magnesium may not be available to microorganisms due to precipitation as insoluble metal hydroxides or carbonates. At lower pH, metals such as aluminum, copper, and zinc may be leached from minerals and may stop the composting process (Ro, et al., 1998). USACE specifications recommend that the compost pH be maintained in the range of 5.5 to 9.0, and preferably within 6.5 to 8.5 (USACE, 2002).

Composting has typically been implemented using one of the three following processes: in-vessel composting, static pile composting, and windrow composting. In-vessel composting involves the placement of compost material in a large containment vessel equipped with a temperature-controlled aeration system. In-vessel systems may be equipped with a mechanism that periodically mixes the compost. In static pile composting, the material to be composted is formed into a pile and aerated by blowing air into the pile through perforated pipes. Static piles are not mechanically mixed, and the aeration system is used to control temperature. In windrow composting, the material to be composted is formed into long parallel rows. The rows are watered occasionally and are periodically turned to promote aeration and control temperature using a specialized piece of equipment called a windrow turner. Of the three types of composting processes, windrow composting has proven to be the most cost effective for soil remediation due to its lower capital and operating costs. Therefore, windrow composting was selected as the representative composting technology for evaluation in the focused feasibility study (FFS) (Shaw, 2003).

Windrow composting could be an effective treatment process to achieve RAOs for nitroaromatic compounds in soil at TNTA. The nitroaromatic compounds (NAC) in soil would be biodegraded or transformed into less toxic products. Composting of explosives such as TNT and 2,4-DNT in soil has been successfully demonstrated. Although composting has been used to effectively treat NAC contaminated soil at some other ordnance facilities, a previous implementation of the technology at PBOW TNTB was not able to attain RGs for ADNTs in soil. As a result, the remedial strategy used to implement composting at TNTB was modified during the remedial action. Instead of treating all soil with concentrations of NACs above RGs, only soil that was a hazardous waste due to elevated levels of 2,4-DNT was treated using composting (to render it nonhazardous). Significantly less soil was treated than initially anticipated, and all of the excavated soil required off-site management at an approved disposal facility. Additionally, the time required to compost a batch of soil was approximately double that originally estimated in the FFS. All of these factors resulted in an escalation of remedial costs above those estimated during the FFS.

Composting does not effectively treat lead-contaminated soil because lead cannot be biodegraded into a less toxic substance. Therefore, a second remedial technology or waste management approach would be required to address lead-contaminated soil. Composting has shown limited effectiveness in treating PCB-contaminated soil. Therefore, soil with concentrations of total PCBs ≥ 50 mg/kg would require off-site management as a PCB remediation waste.

3.3.6.2 Implementability

This process is technically and administratively implementable at TNTA. Previous composting work at PBOW has shown that a treatment building is not required to protect the compost from the weather, even in the winter. Equipment, labor and amendments required for composting are available from local sources, which would lower remedial costs. Treated compost would be transported off site as a nonhazardous waste and used for daily cover at a nearby landfill. The time period required to achieve RAOs is typically longer for this technology than for some of the others discussed in this chapter.

3.3.6.3 Cost

The cost for composting the soil would be high. The main factors contributing to the capital cost are significant equipment rental and labor costs incurred over the relatively lengthy remedial duration. The treated material must be managed off site at an approved disposal facility as a nonhazardous waste.

3.3.6.4 Summary

Composting of contaminated soil at TNTA is a potentially feasible process option for attaining RAOs when the technology is coupled with one or more other remedial technologies. Therefore, the process is retained for further development as a remedial alternative in Chapter 4.0.

3.3.7 Alkaline Hydrolysis

3.3.7.1 Effectiveness

Alkaline hydrolysis involves the addition of an alkaline reagent to increase the pH of contaminated soil, thereby stimulating the hydrolysis of NACs to less toxic reaction products. The technology has most commonly been implemented for the treatment of nitroaromatic explosives by adding calcitic lime, composed of calcium hydroxide ($Ca[OH]_2$), to the contaminated soil. More recently, improved treatment results have been achieved using sodium hydroxide (caustic soda) instead of lime as the alkali reagent.

TNT is susceptible to treatment with alkali as the electronegative nitro groups of TNT reduce the electron density of the aromatic ring and make the molecule subject to nucleophilic attack. The hydroxide ion (OH^-) is a strong nucleophile and has been shown to react with TNT under basic conditions. Nucleophilic substitutions of the nitro and methyl groups of TNT by hydroxide ion are the initial steps in the degradation process that result in a variety of potential reaction products, as shown on Figure 3-3 (Thorn, et al., 2004). Research performed to quantify the TNT-hydroxide reaction rate has identified a multiple step reaction process (Felt, et al., 2001; Mills, 2003). Alkaline hydrolysis has been found to be an effective method of reducing the concentration of TNT in soil, provided enough alkali is added to raise the soil pH to about 12.

Lime application also increases the concentration of calcium ions in the soil solution, and this affects the performance of alkaline hydrolysis by decreasing the adsorption of nitroaromatic compounds on natural clays. Unlike many organic compounds that adsorb readily onto soil organic matter (SOM), the retardation of TNT in soil is not significantly affected by the SOM (Weissmahr, et al., 1999). Rather, the adsorption of TNT is more affected by the clay content of the soil. Planar nitroaromatic compounds with electron-deficient aromatic rings (e.g., TNT, 1,3,5-trinitrobenzene [TNB]) have been shown to adsorb onto both the external siloxane surfaces of 2- and 3-layer clays, and to a lesser extent, the interlamellar siloxane surfaces of 3-layer clays. Based on spectroscopic studies of 1,3,5-TNB adsorption on various clay minerals, it is postulated that this adsorption mechanism involves an n-π electron donor-acceptor (EDA) complex between the unpaired electrons of siloxane oxygens in the clay minerals and the electron-deficient aromatic ring of the TNB (Weissmahr, et al., 1997). Nitroaromatics adsorption on clay is highest when weakly hydrated and less bulky cations (e.g., K^+) predominate in pore water. Conversely, nitroaromatics adsorption on clay is lower in the presence of sodium and calcium, as the large hydration shell of these cations interferes with the EDA complex (Weissmahr, et al., 1999). Therefore, when lime is applied to TNT-contaminated soil, the Ca^{2+} ions in the soil solution promote desorption of TNT. This characteristic of TNT adsorption explains why a study of the reaction kinetics of the TNT alkaline hydrolysis found that the initial mass of TNT in soil immediately following lime treatment was greater than the mass of TNT in the soil prior to treatment (Emmrich, 2003).

The desorption of nitroaromatics from soil caused by liming can increase the efficiency of TNT removal during alkaline hydrolysis by making the TNT more available in the soil solution, but its effect on the removal of other nitroaromatic co-contaminants may be more problematic. Lime treatment is less effective for nitroaromatics such as DNT and ADNT. In one study, the reduction in TNT, 2,4-DNT, 2,6-DNT, 2ADNT, and 4ADNT was measured in soil from two contaminated sites. The soil samples were treated with lime at pH 11 and 12. The results of this study are presented in Table 3-1. Although the removal efficiency of TNT was quite high (98 percent), the removal efficiencies for total DNT isomers were 55 to 64 percent at pH 12. The removal of ADNT isomers was much more variable, as 75 percent of ADNTs were removed from a heavily contaminated soil sample, while total ADNT concentration actually increased by a factor of 16 in soil from a less contaminated site (Emmrich, 2001).

Studies conducted by the U.S. Army Engineer Research and Development Center (USERDC) found that DNT removal is variable with lime treatment, with low to moderate treatment efficiencies (Medina, 2006). A study conducted by USEDRC to determine the effect of mixing regime and soil moisture content on the efficacy of alkaline treatment with TNT-contaminated soil noted an increase in ADNT concentration (approximately 20 to 28 mg/kg) over the 10-day test period (Figure 3-4). Although the report suggested that lime treatment of TNT may have produced the ADNTs, the increased ADNT concentration may have been caused by the aforementioned desorption effect that Ca^{2+} ions have on nitroaromatic compounds bound to clay particles.

Recent work using sodium hydroxide instead of lime to implement alkaline hydrolysis has shown positive results. A pilot test conducted on NAC-contaminated soil at Volunteer Army Ammunition Plant (VAAP) demonstrated that caustic soda treatment achieved RGs at that site for all NAC constituents, including TNT and DNTs. Table 3-2 presents a summary of partial results from this work (Tetra Tech, 2008a). The table presents the results of three treatability tests using varying proportions of caustic soda and ferric chloride in soil. The treatments would also have attained RGs for all NACs in soil at TNTA, with the exception of 2,6-DNT, although the final concentration of total DNTs in the treated soil would have been below the combined TNTA RG for DNTs in all three treatments. Maximum DNT concentrations at TNTA are significantly higher that the initial DNT concentrations in the VAAP treatability test, so additional testing with TNTA soil would be required to confirm effectiveness. The VAAP treatability tests show that the application of caustic soda only was sufficient to attain RGs for soil at VAAP, although the addition of ferric chloride seemed to increase the removal efficiency of DNTs somewhat (Tetra Tech, 2008a).

An alkaline hydrolysis treatability study was recently completed by the Shaw Environmental, Inc. (Shaw) Technology Development Laboratory (TDL). Table 3-3 presents a summary of the results. DNTs were not detected in the untreated soil sample collected from the site so the soil was spiked prior to treatment. Several alkaline reagents were tested and sodium hydroxide was found to perform best. The treatability study confirmed that alkaline hydrolysis was most effective at a soil pH > 12.6, as indicated by the previous Tetra Tech pilot test (Tetra Tech, 2008b). The treatability study found that the TNT concentration could be reduced to the remedial goal within 7 days, but none of the treated samples attained the remedial goal for 2,4-DNT or 2,6-DNT or passed the TCLP test for 2,4-DNT. As shown in Table 3-3, the most effective treatment reduced 2,4-DNT by 97 percent (10,733 to 282 mg/kg) and 2,6-DNT by 32 percent (11,441 to 7,783 mg/kg) within 7 days. The 2,4-DNT concentration in the TCLP leachate from the most effective treatment (0.26 mg/L) was only slightly above the regulatory limit (0.13 mg/L). The LDR regulations require that the concentration of underlying hazardous constituents in soil classified as a hazardous waste be reduced by 90 percent, but no less than 10 times the universal treatment standard for land disposal. Alkaline hydrolysis achieves this level of treatment for 2,4-DNT but not 2,6-DNT. However, only three detections of 2,6-DNT in soil at TNTA exceeded the 280 mg/kg minimum alternative LDR treatment standard, so only a small fraction of the soil will likely require treatment to comply with LDR requirements.

Although none of the treatability tests were sufficiently effective for all nitroaromatic constituents, alkaline hydrolysis might still be an effective treatment for most of the soil contaminated with DNTs. The treatability study data can be used to estimate the fraction of the excavated soil that would meet treatment criteria for on-site or off-site disposal. An alkaline hydrolysis rate constant can be calculated for the reaction of the major NACs with sodium hydroxide assuming that the reaction follows pseudo-first-order kinetics at high concentrations of hydroxide ion (Emmrich, 2001).

$$k = - [\ln (C_t / C_0)] / t$$

In the above equation, k is the rate constant, C_t and C_0 are the concentrations of the NAC at the beginning and end of treatment and t is the treatment time in days. Treated DNT concentrations can be estimated using the alkaline hydrolysis rate constants and the analytical data set for TNTA to determine the fraction of the NACs in soil at TNTA that might not comply with RGs, TCLP limits, and LDR requirements.

$$C_t = C_0 e^{-kt}$$

Using this approach, it is estimated that 10 to 30 percent of the excavated soil might not comply with the most stringent requirements that would allow the treated soil to be placed back on site. This upper end of this range likely overestimates the fraction of soil that would not pass treatment requirements, as excavation, and handling of the soil tends to level out contaminant concentrations somewhat prior to treatment.

The TNT-hydroxide reaction is complex and has the potential to produce numerous undefined reaction products. Several studies have reported that an uncharacterized polymeric material is formed upon the prolonged treatment of TNT with alkali (Thorn, et al., 2004). One study analyzed molecular weight fractions of reaction products generated when an aqueous solution of TNT was treated with KOH at a pH of 13. Approximately 40 percent of the reaction products fell within the 1,000 to 6,000 Dalton molecular weight range (the molecular weight of TNT = 227 Dalton), indicating that a significant percentage of the final reaction products are large molecules that may result from the polymerization of intermediate reaction products (Felt, et al., 2001). Characterization of the polymeric precipitate by ^{13}C and ^{15}N nuclear magnetic resonance suggests that a complex mixture of products is formed. Nuclear magnetic resonance confirms that carbon function groups include methyl, methylene, alcohol/ether, phenolic carboxylic acid, ketone, and possibly quinone. Nitrogen is present in the polymeric material as aminohydroquinone, aminoquinone, heterocyclic, imine or azoxy, nitro, and nitrosophenol among other possibilities (Thorn, et al., 2004).

The toxicity of alkaline hydrolysis reaction products is of interest in evaluating the residual risk that would remain after treatment. The toxicity of TNT-hydroxide reaction products is not well defined, although the limited testing that has been done indicates that the reaction products are less toxic than TNT. The acute toxicity of TNT-contaminated water before and after treatment with NaOH was tested using the standard Microtox® procedure. The EC_{50} of the untreated sample was increased from approximately 2 percent in the untreated sample to 8 percent in 100 mg/L TNT treated solution and 14 percent in a 10 mg/L TNT treated solution. EC_{50} is the effective concentration at which 50 percent of the expected fluorescence from the test bacterium (i.e., *Vibrio fischeri*) is inhibited. Therefore, higher EC_{50} values indicate relative lower toxicity (Hansen, et al., 2001). The toxicity of the polymeric materials formed during the reaction has not been determined (Thorn, et al., 2004).

Alkaline hydrolysis will not effectively treat PAH- or PCB-contaminated soil. Although alkaline hydrolysis may reduce the leachability of lead from soil, it will not reduce the total lead concentration in lead-contaminated soil.

3.3.7.2 Implementability

Field demonstrations of alkaline hydrolysis of TNT-contaminated soil with lime have previously been performed at U.S. Department of Defense facilities in Huntsville, Alabama; Jackson, South Carolina; West Point, New York (Medina, 2006); and Fort Lewis, Washington (Thorn, et al., 2004). As mentioned in the previous section, alkaline hydrolysis of TNT-contaminated soil with caustic soda was demonstrated in a pilot study at VAAP.

Calcitic lime ($Ca[OH]_2$), is typically applied to contaminated soil to raise the pH to 12, as little or no TNT removal is achieved below pH 10 (Hansen, et al., 2001; Emmrich, 1999). For this reason, dolomitic lime, composed principally of $Mg(OH)_2$, is not useful as a treatment reagent for TNT-contaminated soil because the maximum pH developed by $Mg(OH)_2$ is approximately 10.3 due to solubility limitations.

A typical soil treatment recipe uses 2 to 3 parts water to 1 part soil and 1.5 weight percentage lime on a dry soil basis (Medina, 2006). Water is necessary, as the hydrolysis reaction proceeds only when TNT and OH^- are in solution (Brooks, et al., 2003). A USERDC study found the optimal percent moisture content of the reaction mixture to be 25 to 30 percent water (Hansen, et al., 2003).

When the alkaline hydrolysis process using caustic soda was scaled up in field tests at VAAP, the treatment chemicals were applied at the rate of 40 pounds of caustic soda and 1 gallon of 30 percent ferric chloride solution per cubic yard of soil (Tetra Tech, 2008b). The Shaw TDL alkaline hydrolysis treatability study found that the optimum amount of alkaline reagent for TNTC soil is 61 pounds of caustic soda per cubic yard of soil.

The VAAP treatability study determined that the soil pH must be increased to at least 12.6 to ensure effective treatment of NACs. Therefore, the soil should be neutralized if it is to be backfilled in the excavation. At the time the VAAP study was undertaken, a final decision had not been made on the neutralization reagent to use or the application rate that would be required. It was suggested, however, that citric acid might be a good neutralization reagent because it is a weak triprotic organic acid that would provide a carbon substrate to promote nitrite reduction as well as neutralize the excess alkali. As shown in Table 3-2, nitrite is a major reaction product of alkaline hydrolysis, although the levels generated in the VAAP treatability study (≤ 1390 mg/kg) are below the residential soil RBC of 7,800 mg/kg.

Neutralization is a key factor in determining how the treated soil would be managed, because it is easier to increase soil pH than to reduce it. Common methods of lowering soil pH used in agriculture include the addition of acid organic matter that is low in calcium and other non-acid cations (e.g., leaf mold from coniferous trees, pine needles, tan bark, pine sawdust, acid peat moss) and inorganic chemicals such as aluminum sulfate, ferrous sulfate, and elemental sulfur (Brady and Weil, 2002). Alternatively, the alkaline-treated soil might be disposed off site as a nonhazardous waste without neutralization because the upper pH limit for the RCRA corrosivity characteristic does not apply to solids. However, disposal facilities may be reluctant to accept high pH soil (pH > 12.5) even though the corrosivity characteristic defined in the RCRA regulations (40 CFR 261.11) applies only to liquids. The Shaw TDL alkaline hydrolysis treatability study tested several neutralization reagents to determine which would be the most cost effective for full-scale application. The study found ferrous sulfate to be the most economical neutralization agent, with the application of 108 pounds of ferrous sulfate required to neutralize a cubic yard of alkaline-treated soil.

USERDC has noted that the effects of high pH (above or equal to 12) on surface water, groundwater, soil chemistry, soil ecology, and plant growth are not well understood and remain to be addressed in future research (Hansen, et al., 2003). However, naturally alkaline soil ($8.5 \leq pH \leq 10.5$) is known to limit growth in some plant species because micronutrient metals such as iron and zinc are not as bioavailable due to reduced solubility in soil pore water (Brady and Weil, 2002). High sodium concentrations in soil from the application of large amounts of caustic soda may affect the soil structure by increasing colloidal dispersion and reducing the hydraulic conductivity of the soil. High levels of sodium are toxic in some plant species and can affect the uptake and utilization of other cations, such as potassium (Brady and Weil, 2002).

3.3.7.3 Cost

The cost of full-scale treatment is not well documented in the available literature, but the technology is anticipated to be less costly than composting based on reduced batch treatment time.

3.3.7.4 Summary

Alkaline hydrolysis of contaminated soil at TNTA is a potentially feasible process option for attaining RGs in site soil. Therefore, the process is retained for further development as a remedial alternative in Chapter 4.0.

4.0 Development and Detailed Analysis of Remedial Alternatives

4.1 Introduction

The goal of this chapter is to introduce, assess, and communicate the relative costs and benefits of the remedial alternatives selected for careful consideration. Chapter 5.0 provides the comparison and recommendation of a preferred alternative for the sites. The evaluation criteria for this analysis are provided by USEPA in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988). These criteria are based upon the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP), Title 40 CFR, Section 300.430 (USEPA, 1990). The results of this analysis will likely be presented in the proposed plan and record of decision, or other public information documents, following the consideration of state and federal regulatory and community input.

The RI/FS guidance (USEPA, 1988) provides nine evaluation criteria for assessing alternatives within the context of a comprehensive FS. These criteria cover regulatory, technical, cost, institutional, and community considerations. Generally, the two threshold criteria are:

- Protection of human health and the environment
- Compliance with ARARs.

The five balancing criteria are:

- Long-term effectiveness and permanence
- Short-term effectiveness
- Reduction in toxicity, mobility, and volume
- Technical and administrative implementability
- Alternative cost including capital, O&M, and present value costs.

The final two criteria, which often are evaluated subsequent to the initial publication of the FS, are:

- State acceptance
- Community acceptance.

The first seven criteria will be fully evaluated in this FFS. The final two criteria will be discussed briefly in the FFS, as some unofficial public feedback on potential remedial options has already been obtained through preliminary presentations given at the regular public meetings of the PBOW RAB. The last two criteria will be officially evaluated through working-level discussions with state and federal regulators, as well as through the solicitation of community input from more formal public outreach activities. Once all of the FFS criteria have been adequately considered and a remedial alternative is recommended, the proposed removal action will be presented to OEPA and the public in a proposed plan. The proposed plan will be presented at a RAB meeting, where comments will be solicited from the public. Once the public comment period is over, a decision document will be prepared that, when approved, will be the basis for executing the remedial action for soil at TNTA.

The following five alternatives were selected for evaluation:

- Alternative 1 – No Action
- Alternative 2 –Excavation, Windrow Composting, and Off-Site Disposal
- Alternative 3 – Excavation and Off-Site Disposal
- Alternative 4 –Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal.
- Alternative 5 – Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, and On-Site and Off-Site Disposal.

4.2 Alternative 1 - No Action

4.2.1 Description

A no-action alternative is required by the NCP to be carried forward as a baseline for detailed comparison. Under this alternative, no remedial action or monitoring would be conducted for contaminated soil at the site. Thus, this alternative fails to meet the RAOs for soil at TNTA.

4.2.2 Overall Protection of Human Health and the Environment

This alternative would not protect human health and may not protect the environment (refer to Section 1.5 for interpretation of SLERA results) because no action would be taken to reduce the concentrations of COCs in soil to meet OEPA risk management criteria or to prevent current or future receptors from exposure to COCs.

4.2.3 Compliance with ARARs

There are no chemical-specific ARARs for soil. Location- and action-specific ARARs are not applicable to this alternative because no remedial action would be taken.

4.2.4 Long-Term Effectiveness

This alternative would not result in any permanent reduction of potential risk to human health or the environment. No periodic review would take place to evaluate future site conditions.

4.2.5 Reduction of Toxicity, Mobility, or Volume

This alternative does not employ any remedial component that would permanently or significantly reduce the toxicity, mobility, or volume of contaminants in soil.

4.2.6 Short-Term Effectiveness

There are no short-term impacts from this alternative because no remedial action is taken.

4.2.7 Implementability

There are no technical or administrative implementation issues associated with this alternative.

4.2.8 Cost

There is no cost impact associated with this alternative.

4.2.9 State Acceptance

It is highly unlikely that OEPA would accept the no-action alternative to address soil contamination at TNTA because this alternative does not protect human health.

4.2.10 Community Acceptance

It is highly unlikely that the community would accept the no-action alternative to address soil contamination at TNTA because this alternative does not protect human health.

4.3 Alternative 2 – Excavation, Windrow Composting, and Off-Site Disposal

4.3.1 Description

This alternative involves the excavation of contaminated soil within proposed remediation areas, windrow composting of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT, off-site disposal of composted soil and untreated soil at an approved nonhazardous waste landfill, and off-site disposal of soil that would be a hazardous waste due to elevated concentrations of lead or PCBs in a RCRA Subtitle C treatment, storage, and disposal facility (TSDF).

The windrow composting facility would be located within the area of contamination at TNTA. The selection of a site would be made during the remedial design (RD) phase of the project. The optimum size of the treatment facility is influenced by the trade-offs between fixed and variable project costs. Although assumptions concerning the size of the composting facility are used in this FFS to enable remediation costs to be estimated, the actual size of the treatment facility would be optimized during the RD. For this FFS, the conceptual design of the composting technology was based on previous experience with composting at PBOW. Design factors that significantly influence the cost of the remedial technology (e.g., size of the treatment area, windrow size, composting batch times, type and cost of equipment used, type and cost of operating labor, management of waste residuals) were based on the actual field implementation of the technology at TNTB.

The treatment area previously prepared at PBOW for windrow composting contaminated soil from the Pentolite Road Red Water Ponds would be used for alkaline hydrolysis and composting operations. The composting treatment area would be 800 feet long by 260 feet wide and surrounded by an earthen berm to contain storm water runoff. Treatment operations would be conducted in the open. The treatment area is graded and compacted to a 2 percent slope to control storm water. The treatment area is not covered with an artificial surface such as asphalt or concrete. The windrows would be constructed within the treatment area and stockpiles of amendments, untreated soil and treated compost would be staged in the area.

Storm water would be pumped from sumps on the lower end of the treatment area to a 260-foot-long by 30-foot-wide by 3-foot-deep contact water retention basin. The basin is lined with 60-mil plastic. Water in the basin would be applied to the windrows as needed to maintain the moisture content of the compost. Excess water would be trucked off site to an industrial wastewater treatment facility. No on-site treatment of contact water would be required.

Soil within the remediation areas would be excavated and screened to remove oversize material and reduce particle size to increase the efficiency of the composting process. The excavated soil would be trucked to the composting treatment area for screening. The screened soil would be stockpiled at the compost facility for treatment or disposal. Soil adhering to the oversize material would be removed so that the oversize material would be returned to the excavation. Any oversize material not appropriate for use as backfill would be disposed off site at an approved disposal facility.

Amendments would be brought to the facility as needed so that large amounts of amendments would not be required to be stored on site. This minimizes the cost of amendment storage as well as odor problems associated with manure, as the odor increases with storage duration. Equipment, labor, and amendments needed to run the composting operation would be available locally.

It is assumed that the compost would consist of 25 percent by volume (74.7 percent by weight) contaminated soil, 72 percent by volume (19.6 percent by weight) straw, and 3 percent by volume (5.7 percent by weight) chicken manure. The compost would be constructed into windrows 16 feet wide by 6 feet high. A treatment cycle for each batch is assumed to require 6 weeks, 5 weeks for treatment and 1 week for curing and analytical testing. The treatment cycles for windrows would be staggered so that the windrows did not complete the treatment cycle at the same time.

The compost would be turned periodically with the windrow turner to mechanically aerate the material. After the compost is turned, microorganisms within the pile aerobically degrade organic compounds until the available oxygen within the pile is utilized. Beyond this point, further contaminant degradation is achieved through an anaerobic process. The periodic turning of the compost pile permits the composting process to alternate between aerobic and anaerobic treatment phases. This is the most effective approach to the biological degradation of nitroaromatic explosives.

Precompliance testing of the compost would consist of sampling the compost immediately after formation and one a week during treatment. One composite sample would be collected from each windrow each week and analyzed as follows: TNT colorimetric field test and total NACs (off-site laboratory).

If the precompliance results indicate that cleanup levels have been achieved, compliance samples would then be collected to confirm the results of the precompliance testing. For cost estimating purposes in this FFS, it assumed that one composite compliance sample would be collected per windrow. The actual sampling and analytical strategy employed during remediation would be subject to negotiation between OEPA and USACE.

Soil that passes the TCLP tests may be disposed in a nonhazardous waste landfill. Under this alternative, any soil classified as hazardous waste would be composted on site to achieve nonhazardous waste classification and comply with LDR requirements prior to land disposal in a Subtitle D landfill. It is estimated that, of the 17,157 cubic yards of soil that would be excavated under this approach, 12,380 cubic yards (consolidated basis) would be shipped untreated for disposal at a nonhazardous waste landfill, while 3,319 cubic yards would be composted prior to disposal at a nonhazardous soil waste landfill. Approximately 1,339 cubic yards of soil deemed hazardous due to elevated concentrations of lead would be shipped off site for treatment/disposal at an approved hazardous waste TSDF. Of this lead-contaminated soil, approximately 40 percent (544 cubic yards) is estimated to be hazardous with respect to 2,4-DNT as well. Finally, 119 cubic yards of PCB remediation waste would be treated and/or disposed at a TSCA-approved TSDF; this material is expected to be hazardous with respect to 2,4-DNT and a portion of it (approximately 60 cubic yards) is expected to have hazardous levels of lead as well.

4.3.2 Overall Protection of Human Health and the Environment

Alternative 2 would protect human health by excavating contaminated soil with concentrations of COCs above the RGs. Ecological receptors may also benefit, in that removal of the most highly contaminated soil would lower the EHQs calculated for various receptors in the ecological risk assessment. The soil removal would also mitigate the migration of soil contaminants to groundwater.

The alternative provides adequate protection against the potential hazards of contaminants in excavated soil through the combination of treatment and waste management technologies. Once the contaminated soil was excavated, the soil with elevated concentrations of 2,4-DNT would be biologically treated via windrow composting to render it nonhazardous for disposal. Soil hazardous due to lead and PCB remediation waste would be managed off site at a hazardous waste TSDF.

4.3.3 Compliance with ARARs

The alternative would comply with all ARARs. There are no chemical-specific ARARs for soil. The location- and action-specific ARARs for Alternative 2 are presented in Appendix C of the FFS (Shaw, 2003). None of the location-specific ARARs were identified as applicable for this remedial alternative. The alternative would comply with all action-specific ARARs, in particular the regulations that deal with the identification, storage, and disposal of hazardous waste.

4.3.4 Long-Term Effectiveness

The long-term effectiveness of Alternative 2 is achieved through the removal of soil contaminated with COC at concentrations above the RGs and treatment of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT. As previously discussed, the alternative would be effective in protecting potential human receptors from direct exposure to COCs in soil. The alternative may also benefit ecological receptors by significantly reducing the EHQs associated with soil contamination at the sites. The removal and treatment of the most highly contaminated soil would also reduce the mass transport of soil contaminants to groundwater.

The alternative would not require the maintenance of any long-term controls at the site to manage residual risk from direct exposure to soil.

4.3.5 Reduction of Toxicity, Mobility, or Volume

Alternative 2 would satisfy the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances as their principal element. The excavation and treatment of contaminated soils by windrow composting would reduce the toxicity and mobility of nitroaromatic compounds in soil through a combination of biological degradation and immobilization via covalent binding with humic substances in the compost.

Under this alternative, 15,698 cubic yards of treated and untreated soil (consolidated basis) would be managed for disposal at an approved nonhazardous waste landfill, and 1,339 cubic yards of lead-contaminated soil (consolidated basis) would be treated and disposed of in a Subtitle C TSDF. An estimated 544 cubic yards of this lead-contaminated material is expected to be hazardous with respect to 2,4-DNT. An additional 119 cubic yards of PCB remediation waste would not be treated prior to being hauled off site for treatment and/or disposed at a TSCA-approved TSDF. The 119 cubic yards of this PCB waste material is expected to be hazardous with respect to 2,4-DNT, and a portion of it (approximately 60 cubic yards) is expected to have hazardous levels of lead as well. Table 2-8 provides a detailed breakdown of excavated soil volumes on a site-by-site basis. Approximately 80 percent of the excavated soil would not be treated prior to disposal.

4.3.6 Short-Term Effectiveness

The implementation of Alternative 2 does not present any significant health threats to the community. The excavation and treatment of contaminated soils would be performed within the confines of PBOW at a sufficient distance from the property boundaries that the nearby community should not be affected. The composting process would be managed to minimize the generation of dust or nuisance odors during remediation. Proper decontamination and waste transportation practices would be followed to prevent the spread of contamination when equipment or waste materials left the site.

Alternative 2 does not present site workers with any unusual health or safety concerns for a remediation project. A hazard evaluation would be performed prior to the commencement of the removal action, and a health and safety plan would be followed during site activities to ensure that risks to workers were minimized. Remediation workers would be supplied with any protective gear required to conduct operations in a safe manner.

Environmental impacts during remediation would be mitigated primarily through measures designed to ensure that contamination was not spread during remedial activities. These measures include dust controls during excavation and treatment, decontamination procedures for equipment and personnel, and storm water run-off and run-on controls.

It is estimated that 18 to 24 months would be required to complete remedial activities under Alternative 2 at TNTA in one field event, from the initiation of work plans to backfilling excavated areas and disposal of excavated soil and treatment residuals. Table 4-1 provides additional detail on the individual work elements involved in the execution of this alternative.

4.3.7 Implementability

Windrow composting is a reliable technology, as it has been implemented at a number of remediation sites to treat soil contaminated with nitroaromatic explosives, PAHs, and other chemicals, such as pesticides. Composting technology has also been widely used in the treatment of agricultural wastes and the management of treatment residuals from municipal wastewater treatment plants. Equipment, personnel, and amendments are available locally.

Compliance sampling of the sidewall and bottom areas of the excavation and analysis of the soil samples for COC can be used to monitor the effectiveness of excavation in removing soil contaminated above RGs.

The effectiveness of the composting process is monitored by periodic sampling and analysis of the compost during and after the treatment process. Colorimetric field analytical methods would be utilized during precompliance testing to augment analytical work in off-site labs to lower analytical costs. Standard fixed-base laboratory analyses would be used for final compliance sampling after treatment was complete for each batch of compost. The treatment process could be extended for any composted material that failed compliance testing.

The alternative does not preclude additional remedial action for soil if needed.

Alternative 2 does not present any unusual regulatory requirements that would compromise the administrative feasibility of the remedial approach. OEPA would need to approve the disposal facility used for any waste materials managed off site.

4.3.8 Cost

The detailed cost evaluation for the implementation of Alternative 2 for TNTA is presented in Table 4-1. The estimated capital cost for Alternative 2 is $5.2 million for TNTA.

A contingency of 30 percent has been added to the cost estimate to account for uncertainty in the estimated volume of soil requiring remediation and to provide an allowance for cost elements that are not identifiable at the present time. Due to the relatively short time frame over which the remedial alternative would be completed, all costs associated with its implementation are classified as capital costs. Accordingly, there are no O&M costs for this alternative, and the present value cost is equivalent to the capital cost.

4.3.9 State Acceptance

This criterion will be evaluated in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.3.10 Community Acceptance

This criterion will be evaluated in more detail in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.4 Alternative 3 – Excavation and Off-Site Treatment/Disposal

4.4.1 Description

Alternative 3 combines excavation and off-site treatment and disposal in order to achieve the RAOs for soil at TNTA. No on-site treatment would be performed under Alternative 3. The proposed approach is to excavate all the areas in which the concentrations of the COCs in soil exceed the RGs defined in Chapter 2.0. The total estimated volume of contaminated soil from TNTA is 17,157 cubic yards (consolidated basis). Once this soil is excavated, the total volume of unconsolidated material is estimated to be 22,304 cubic yards (30 percent swell).

Soil within the remediation areas would be excavated and screened to remove oversize material. The excavated soil would be trucked to the staging area for screening. The screened soil would be stockpiled at the staging area for subsequent off-site disposal. Soil adhering to the oversize material would be removed so that the oversize material can be returned to the excavation. Any oversize material not appropriate for use as backfill would be disposed off site along with the rest of the contaminated soil.

Following excavation of the contaminated soil, representative soil samples from each area would be analyzed using the TCLP test. Based on existing soil data from TNTA, the consolidated volume of excavated soil that may be classified as a characteristic hazardous waste or PCB remediation waste is estimated at 4,777 cubic yards. The volume of RCRA/TSCA waste is estimated to be 28 percent of the total excavated soil.

Section 2.5.1 of the FFS summarizes the applicable regulations used to determine if the excavated soil is a hazardous waste. Soil that passes the TCLP tests and complies with all LDR requirements can be disposed in a nonhazardous waste landfill. Therefore, it is estimated that, of the 17,157 cubic yards of soil that would be excavated under this approach, 12,380 cubic yards could be shipped for disposal at a nonhazardous solid waste landfill. The remaining 4,777 cubic yards would be manifested and shipped for disposal at an off-site hazardous waste TSDF. The TSDF would treat any waste material that did not comply with the LDR treatment standards prior to disposal.

4.4.2 Overall Protection of Human Health and the Environment

Alternative 3 would protect human health by excavating contaminated soil with concentrations of COCs above the RGs. Ecological receptors may also benefit, in that removal of the most contaminated soil would result in lowering the EHQs calculated for various receptors in the ecological risk assessment. The soil removal would also mitigate the migration of soil contaminants to groundwater.

The alternative provides adequate protection against the potential hazards of contaminants in excavated soil by disposing of the contaminated soil in a disposal facility designed, constructed, and maintained to permanently manage such waste materials. Once the contaminated soil was excavated, soil classified as hazardous based on TCLP testing would be treated and/or disposed of in a RCRA Subtitle C TSDF. Nonhazardous soil would be disposed of in an approved Subtitle D solid waste landfill. PCB remediation waste would be treated and/or disposed in a TSCA-approved TSDF.

4.4.3 Compliance with ARARs

The alternative would comply with all ARARs. There are no chemical-specific ARARs for soil. The location- and action-specific ARARs for Alternative 3 are presented in Appendix C of the FFS (Shaw, 2003). None of the location-specific ARARs were identified as applicable for this alternative. The remedial alternative would comply with all the action-specific ARARs, in particular the regulations that deal with the identification, storage, and disposal of hazardous waste.

4.4.4 Long-Term Effectiveness

The long-term effectiveness of Alternative 3 is achieved through the removal of contaminated soil with COCs at concentrations above RGs. As previously discussed, the alternative would be effective in protecting potential receptors from direct exposure to COCs in soil. The removal of the most highly contaminated soil would also reduce the mass transport of soil contaminants to groundwater.

The alternative would not require the maintenance of any long-term controls at the site to manage residual risk from direct exposure to soil.

4.4.5 Reduction of Toxicity, Mobility, or Volume

Although Alternative 3 would reduce the mass and volume of contaminated media remaining at the site, no net reductions in contaminant mass would be achieved unless a process such as incineration were performed at the TSDF, because COCs are transferred from one location to another. As a result**,** Alternative 3 would not comply with the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances as their principal element. However, transferring waste material from an uncontrolled disposal site to a managed disposal facility that is designed and constructed to prevent the release of contaminants to the environment would restrict the mobility of COCs in excavated soil.

4.4.6 Short-Term Effectiveness

The implementation of Alternative 3 would not present any significant health threats to the community. The excavation of contaminated soils would be performed within the confines of PBOW at a sufficient distance from the property boundaries that the nearby community should not be affected. Proper decontamination and waste transportation practices would be followed to prevent the spread of contamination when equipment or waste materials leave the site.

Alternative 3 does not present site workers with any unusual health or safety concerns for a remediation project. A hazard evaluation would be performed prior to the commencement of the removal action, and a health and safety plan would be followed during site activities to ensure that risks to workers were minimized. Remediation workers would be supplied with any protective gear required to conduct operations in a safe manner.

Environmental impacts during remediation would be mitigated primarily through measures designed to ensure that contamination is not spread during remedial activities. This includes measures such as dust controls during excavation, decontamination procedures for equipment and personnel, and storm water run-off and run-on controls.

It is estimated that 12 to 18 months would be required to complete remedial activities, from the initiation of work plans to disposal of contaminated soil and backfilling excavated areas. Table 4-3 provides additional detail on the individual work elements involved in the execution of this alternative.

4.4.7 Implementability

This alternative is technically and administratively implementable.

Compliance sampling of the sidewall and bottom areas of the excavation and analysis of the soil samples for COCs can be used to monitor the effectiveness of excavation in removing soil contaminated above RGs.

The alternative does not preclude additional remedial action for soil if needed.

Alternative 3 does not present any unusual regulatory requirements that would compromise the administrative feasibility of the remedial approach. OEPA would have to approve the disposal facility used for any waste materials managed off site.

4.4.8 Cost

The detailed cost evaluation associated with the implementation of Alternative 3 for TNTA is presented in Table 4-3. The estimated capital cost for Alternative 3 is $4.7 million.

A contingency of 30 percent has been added to the cost estimate to account for uncertainty in the estimated volume of soil requiring remediation and to provide an allowance for cost elements that are not identifiable at the present time. Due to the relatively short time frame over which the remedial alternative would be completed, all costs associated with its implementation are classified as capital costs. Accordingly, there are no O&M costs for this alternative, and the present value cost is equivalent to the capital cost.

4.4.9 State Acceptance

This criterion will be evaluated in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.4.10 Community Acceptance

This criterion will be evaluated in more detail in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.5 Alternative 4 – Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal

4.5.1 Description

This alternative involves the excavation of contaminated soil within proposed remediation areas, windrow composting of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT, chemical stabilization of soil that would be a hazardous waste due to elevated concentrations of lead, and off-site disposal of all treated and untreated soil as a nonhazardous waste in a solid waste landfill. PCB remediation waste would be managed off site at a hazardous waste TSDF. This alternative is similar to Alternative 2, with the exception that lead-contaminated soil under Alternative 4 would not be treated on site but would be disposed of off site as a nonhazardous waste. Approximately 17,157 cubic yards of consolidated soil would be excavated, with 3,803 cubic yards of consolidated soil treated using windrow composting. An estimated 1,339 cubic yards of consolidated soil would be chemically stabilized. It is anticipated that 544 cubic yards of the composted material would require stabilization because of hazardous lead concentrations. In all, approximately 4,658 cubic yards of treated soil and 12,380 cubic yards of nonhazardous, untreated soil would be disposed of off site in a solid waste landfill. Another 119 cubic yards of PCB remediation waste would be managed in an approved TSCA TSDF. The 119 cubic yards of this PCB waste material is expected to be hazardous with respect to 2,4-DNT, and a portion of it (approximately 60 cubic yards) is expected to have hazardous levels of lead as well.

A detailed description of windrow composting is presented in the description of Alternative 2 in Section 4.3.1. Windrow composting under Alternative 4 is similar. Please refer to Section 4.3.1 for additional details on this technology. Soil contaminated with hazardous levels of both 2,4-DNT and lead would be composted first and then chemically stabilized.

Lead-contaminated soil under this alternative would be chemically stabilized using the Maectite® process developed by Sevenson Environmental Services, Inc. Maectite is a cost-effective technology because the chemical can be mixed into the soil using an excavator. The Maectite technology has been used successfully in the past at PBOW to stabilize lead-contaminated soil.

4.5.2 Overall Protection of Human Health and the Environment

Alternative 4 would protect human health by excavating contaminated soil with concentrations of COCs above the RGs. Ecological receptors may also benefit, in that removal of the most contaminated soil would result in lowering the EHQs calculated for various receptors in the ecological risk assessment. The soil removal will also mitigate the migration of soil contaminants to groundwater.

The alternative provides adequate protection against the potential hazards of contaminants in excavated soil through the combination of treatment and waste management technologies. Once the contaminated soil is excavated, the soil with elevated levels of 2,4-DNT would be biologically treated via windrow composting to render it nonhazardous for disposal. Soil with elevated lead concentrations would be chemically stabilized to render it nonhazardous. Treated and untreated soil that complies with LDR requirements and that is not a hazardous waste would be disposed of off site as a nonhazardous waste in a Subtitle D landfill.

4.5.3 Compliance with ARARs

The alternative would comply with all ARARs. There are no chemical-specific ARARs for soil. The location- and action-specific ARARs for Alternative 4 are presented in Appendix C of the FFS (Shaw, 2003). None of the location-specific ARARs were identified as applicable for this remedial alternative. The alternative would comply with all action-specific ARARs, in particular the regulations that deal with the identification, storage, and disposal of hazardous waste.

4.5.4 Long-Term Effectiveness

The long-term effectiveness of Alternative 4 is achieved through the removal of soil contaminated with COCs at concentrations above the RGs and treatment of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT and lead. As previously discussed, the alternative would be effective in protecting potential receptors from direct exposure to COCs in soil. The removal of the most highly contaminated soil would also reduce the mass transport of soil contaminants to groundwater.

The alternative would not require the maintenance of any long-term controls at the site to manage residual risk from direct exposure to soil.

4.5.5 Reduction of Toxicity, Mobility, or Volume

Alternative 4 would comply with the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances as their principal element. The treatment of contaminated soils by windrow composting would reduce the toxicity and mobility of nitroaromatic compounds in soil through a combination of biological degradation and immobilization via covalent binding with humic substances in the compost. Treatment of lead-contaminated soil using chemical stabilization reduces the mobility of lead in the treated soil.

Under this alternative, 17,038 cubic yards of treated and untreated soil would be managed for disposal at an approved nonhazardous waste landfill and 119 cubic yards of PCB remediation waste would be managed off site at a TSCA-approved TSDF. Approximately 27 percent of the excavated soil would be treated prior to disposal.

4.5.6 Short-Term Effectiveness

The implementation of Alternative 4 would not present any significant health threats to the community. The excavation and treatment of contaminated soils would be performed within the confines of PBOW at a sufficient distance from the property boundaries that the nearby community should not be affected. The composting and stabilization processes would be managed to minimize the generation of dust or nuisance odors during remediation. Proper decontamination and waste transportation practices would be followed to prevent the spread of contamination when equipment or waste materials leave the site.

Alternative 4 does not present site workers with any unusual health or safety concerns. A hazard evaluation would be performed prior to the commencement of the removal action, and a health and safety plan would be followed during site activities to ensure that risks to workers were minimized. Remediation workers would be supplied with any protective gear required to conduct operations in a safe manner.

Environmental impacts during remediation would be mitigated primarily through measures designed to ensure that contamination was not spread during remedial activities. This includes measures such as dust controls during excavation and treatment, decontamination procedures for equipment and personnel, and storm water run-off and run-on controls.

It is estimated that 19 to 25 months would be required to complete remedial activities under Alternative 4 in one field event, from the initiation of work plans to backfilling excavated areas and disposal of treatment residuals. Table 4-5 provides additional detail on the individual work elements involved in the execution of this alternative.

4.5.7 Implementability

Windrow composting is a reliable technology, as it has been implemented at a number of remediation sites to treat soil contaminated with nitroaromatic explosives, PAHs, and other chemicals, such as pesticides. Composting technology has also been widely used in the treatment of agricultural wastes and the management of treatment residuals from municipal wastewater treatment plants. Chemical stabilization has been used at numerous sites to immobilize lead in soil both as an in situ and ex situ technology. As a result, a number of contractors are experienced in implementing these technologies, and equipment is readily available. Equipment, personnel, and amendments are available locally. The chemical stabilization reagent is available from Sevenson Environmental Services, Inc.

Compliance sampling of the sidewall and bottom areas of the excavation and analysis of the soil samples for COCs can be used to monitor the effectiveness of excavation in removing soil contaminated above RGs.

The effectiveness of the composting process is easily monitored by periodic sampling and analysis of the compost during and after the treatment process. Colorimetric field analytical methods may be utilized during precompliance testing to augment analytical work performed by off-site laboratories to lower analytical costs. Standard fixed-base laboratory analyses would be used for final compliance sampling after treatment was complete for each batch of compost. The composting treatment process could be extended for any composted material that fails compliance testing.

The stabilization process is monitored after treatment is complete by TCLP testing to demonstrate that the leachable concentrations of lead in samples of the stabilized matrix are below the maximum levels permissible in the land disposal restrictions. The compressive strength of the stabilized material is also typically tested to ensure it is suitable as structural backfill. If the stabilized soil did not pass the TCLP test, the soil could be reprocessed.

The alternative does not preclude additional remedial action for soil if needed.

Alternative 4 does not present any unusual regulatory requirements that would compromise the administrative feasibility of the remedial approach. OEPA would have to approve the disposal facility used for any waste materials managed off site.

4.5.8 Cost

The detailed cost evaluation for the implementation of Alternative 4 for TNTA is presented in Table 4-5. The estimated capital cost for Alternative 4 is $5.1 million.

A contingency of 30 percent has been added to the cost estimate to account for uncertainty in the estimated volume of soil requiring remediation and to provide an allowance for cost elements that are not identifiable at the present time. Due to the relatively short time frame over which the remedial alternative would be completed, all costs associated with its implementation are classified as capital costs. Accordingly, there are no O&M costs for this alternative, and the present value cost is equivalent to the capital cost.

4.5.9 State Acceptance

This criterion will be evaluated in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.5.10 Community Acceptance

This criterion will be evaluated in more detail in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.6 Alternative 5 – Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, and On-Site and Off-Site Disposal

4.6.1 Description

This alternative involves the excavation of contaminated soil within proposed remediation areas, alkaline hydrolysis of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT, windrow composting of alkaline hydrolysis treated soil that does not meet remedial goals for on-site disposal, chemical stabilization of soil that would be a hazardous waste due to elevated concentrations of lead, on-site disposal of alkaline hydrolysis treated and composted soil, and off-site disposal of all untreated soil and lead-stabilized soil at a nonhazardous solid waste landfill. PCB remediation waste would be managed off site at a TSCA-approved TSDF. Approximately 17,157 cubic yards of consolidated soil would be excavated, with 3.803 cubic yards of consolidated soil treated using alkaline hydrolysis/windrow composting and 1,339 cubic yards of consolidated soil chemically stabilized for lead. An estimated 119 cubic yards of soil would be disposed of at a TSCA-approved TSDF as a PCB remediation waste. The 119 cubic yards of this PCB waste material is expected to be hazardous with respect to 2,4-DNT, and a portion of it (approximately 60 cubic yards) is expected to have hazardous levels of lead as well.

Soil within the remediation areas would be excavated and screened to remove oversize material and reduce particle size to increase the efficiency of the alkaline hydrolysis and composting processes. The excavated soil would be trucked to the treatment area for screening. The screened soil would be stockpiled at the treatment facility for treatment or disposal. Soil adhering to the oversize material would be removed so that the oversize material could be returned to the excavation. Any oversize material not appropriate for use as backfill would be disposed off site at an approved disposal facility.

For this FFS, the conceptual design of the alkaline hydrolysis technology was based on both previous experience at VAAP (Tetra Tech, 2008b) and the recently completed Shaw TDL alkaline hydrolysis treatability study. Alkaline hydrolysis would be implemented by adding caustic soda and ferric chloride to the excavated soil. The soil would be neutralized before placement back on site. NAC-contaminated soil would be treated in 300-cubic yard batches, approximately 52 feet square by 3 feet deep per treatment cell. It is estimated that the remediation field crew could have four or five treatment cells in process at the same time within the treatment area. Nine or 10 batches would be required to complete treatment at TNTA. Approximately 61 pounds of caustic soda would be required per cubic yard of soil. Caustic soda pellets would be spread across the soil in the treatment cell and mixed into the soil using an excavator and/or wheel loader. Water would be applied to the soil to promote dissolution of the caustic soda. A 30 percent solution of ferric chloride is sprayed on the soil at the ratio of 1 gallon of $FeCl_3$ solution per cubic yard of soil. The batch of soil would be turned every other day and moisture applied as necessary to keep the soil near saturation. The hydrolysis reaction should be complete in about seven days based on the alkaline hydrolysis treatability study and previous field tests at VAAP. At this point, ferrous sulfate would be added to the soil to neutralize the caustic soda. It is assumed that another three days would be required with some additional mixing to lower the pH of the soil. Approximately 108 pounds of ferrous sulfate would be required to neutralize all the caustic soda applied to the soil based on the treatability study results.

Alkaline hydrolysis treated soil that did not pass the TCLP test for 2,4-DNT or that did not comply with remedial goals or alternative LDR requirements for nitroaromatic constituents in contaminated soil would be treated via windrow composting until these criteria are met. The goal of alkaline hydrolysis/windrow composting treatment is to allow the treated soil to be placed back on site. Soil that could not be treated to remedial goals for all COCs would be managed as a nonhazardous waste for off-site disposal provided it passed TCLP and complied with LDR requirements. For cost estimating purposes, it is assumed that 20 percent of the alkaline hydrolysis treated soil would need to be composted. The composting operation would be similar to that described for Alternative 2, and additional details about the operation are presented in Section 4.3.1. All of this treated and composted material is assumed to meet the criteria for on-site placement, except for that which does not meet remedial goals, TCLP, or LDR requirements for lead.

Lead-contaminated soil under this alternative would be chemically stabilized using the Maectite process developed by Sevenson Environmental Services, Inc. Maectite is a cost-effective technology because the chemical can be mixed into the soil using equipment already on site, such as an excavator. The Maectite technology has been used successfully in the past at PBOW to stabilize lead-contaminated soil for off-site disposal. It is possible that alkaline hydrolysis treatment of the NACs with caustic soda would also stabilize the lead-contaminated soil, such that it would meet TCLP for lead without Maectite treatment. The need for treatment of lead-contaminated soil with Maectite will be determined in the field during remediation activities. It is assumed in this addendum that stabilization of lead-contaminated soils will be required after treatment with caustic soda.

The treatment area previously prepared at PBOW for windrow composting contaminated soil from the Pentolite Road Red Water Ponds would be used for alkaline hydrolysis, composting, and stabilization operations. The treatment cells would be constructed within the treatment area, and stockpiles of treated and untreated soil would be staged in the area. Storm water would be pumped from sumps on the lower end of the treatment area to a 260-foot-long by 30-foot-wide by 3-foot-deep contact water retention basin. The basin would be lined with 60-mil plastic. Water in the basin would be applied to the soil as needed to maintain the moisture content during treatment. Excess water would be trucked off site to an industrial wastewater treatment facility. No on-site treatment of contact water would be required.

Precompliance (in-process) testing of the alkaline hydrolysis-treated soil involves taking samples for field pH measurements to determine if treatment is uniform throughout the batch. Compliance testing for the alkaline hydrolysis technology would be performed in two phases. The first phase would take place at the end of treatment with caustic soda and ferric chloride (~ day 7). A composite sample would be collected from each 300-cubic yard batch and analyzed for total NACs, nitrate/nitrite, and TCLP 2,4-DNT. The second phase of compliance testing would be performed at the end of soil neutralization (~ day 10). A composite sample would be collected from each 300-cubic yard batch and analyzed for pH (field test) and nitrate/nitrite (offsite lab).

Precompliance testing of the compost would consist of sampling the compost immediately after formation and once a week during treatment. One composite sample would be collected from each windrow each week and analyzed as follows: TNT colorimetric field test, PAH qualitative colorimetric field test, total NACs (off-site laboratory) and total PAHs (off-site laboratory).

If the precompliance results indicate that cleanup levels had been achieved, compliance samples would then be collected to confirm the results of the definitive analyses used for precompliance testing. For cost estimating purposes in this FFS, it assumed that one composite compliance sample would be collected per windrow. The actual sampling and analytical strategy employed during remediation would be subject to a project delivery team decision.

Compliance testing for the chemical stabilization technology involves collecting two composite samples from the entire volume of stabilized soil and analysis for TCLP lead. This sampling and analytical strategy is proposed as the basis for estimating remedial costs only. The actual sampling and analytical strategy employed during remediation would be subject to a project delivery team decision.

4.6.2 Overall Protection of Human Health and the Environment

Alternative 5 would protect human health by excavating contaminated soil with concentrations of COCs above the RGs. Ecological receptors may also benefit, in that removal of the most contaminated soil would result in lowering the EHQs calculated for various receptors in the ecological risk assessment. The soil removal would also mitigate the migration of soil contaminants to groundwater.

The alternative provides adequate protection against the potential hazards of contaminants in excavated soil through the combination of treatment and waste management technologies. Once the contaminated soil was excavated, the soil with elevated levels of 2,4-DNT would be chemically treated via alkaline hydrolysis to render it nonhazardous for disposal. Alkaline hydrolysis treated soil that did not pass the TCLP test for 2,4-DNT or that did not comply with remedial goals or LDR requirements for nitroaromatic constituents would be treated via windrow composting until these criteria are met. Soil with elevated lead concentrations would be chemically stabilized to render it nonhazardous. Alkaline hydrolysis and composted soil that met remedial goals and LDR requirements would be placed back on site. Untreated soil and lead stabilized soil that complied with LDR requirements and that was not a hazardous waste would be disposed of off site as a nonhazardous waste in a Subtitle D landfill.

4.6.3 Compliance with ARARs

The alternative would comply with all ARARs. There are no chemical-specific ARARs for soil. The location- and action-specific ARARs for Alternative 5 are presented in Appendix C of the FFS (Shaw, 2003). None of the location-specific ARARs were identified as applicable for this remedial alternative. The alternative would comply with all action-specific ARARs, in particular the regulations that deal with the identification, storage, and disposal of hazardous waste.

4.6.4 Long-Term Effectiveness

The long-term effectiveness of Alternative 5 is achieved through the removal of soil contaminated with COC at concentrations above the RGs and treatment of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT and lead. As previously discussed, the alternative would be effective in protecting potential receptors from direct exposure to COCs in soil. The removal of the most highly contaminated soil would also reduce the mass transport of soil contaminants to groundwater.

The alternative would not require the maintenance of any long-term controls at the site to manage residual risk from direct exposure to soil.

4.6.5 Reduction of Toxicity, Mobility, or Volume

Alternative 5 would comply with the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances as their principal element. The treatment of contaminated soils by alkaline hydrolysis and composting would reduce the toxicity and mobility of nitroaromatic compounds in soil. Treatment of lead-contaminated soil using chemical stabilization reduces the mobility of lead in the treated soil.

Under this alternative, 13,719 cubic yards of untreated and lead-stabilized soil would be managed for disposal at an approved nonhazardous solid waste landfill, 119 cubic yards of PCB remediation waste would be managed off site at a TSCA-approved TSDF, and 3,319 cubic yards of alkaline hydrolysis/composted soil would be placed back on site. Approximately 27 percent of the excavated soil would require treatment prior to disposal (including on-site placement). Treatment is performed only on soil that is classified as a hazardous waste at the time of excavation because it is not cost-effective to treat low concentrations of COCs that are present in soil above the RGs but below regulatory levels that require classification as a hazardous waste.

4.6.6 Short-Term Effectiveness

The implementation of Alternative 5 would not present any significant health threats to the community. The excavation and treatment of contaminated soil would be performed within the confines of PBOW at a sufficient distance from the property boundaries that the nearby community should not be affected. The alkaline hydrolysis, composting, and stabilization processes would be managed to minimize the generation of dust or nuisance odors during remediation. Proper decontamination and waste transportation practices would be followed to prevent the spread of contamination when equipment or waste materials left the site.

Alternative 5 involves the storage and handling of very corrosive materials, such as caustic soda and ferric chloride solution. The material handling processes should be carefully designed to minimize worker contact with corrosive materials. A hazard evaluation would be performed prior to the commencement of the removal action, and a health and safety plan would be followed during site activities to ensure that risks to workers were minimized. Remediation workers would be supplied with any protective gear required to conduct operations in a safe manner.

Environmental impacts during remediation would be mitigated primarily through measures designed to ensure that contamination was not spread during remedial activities. This includes measures such as dust controls during excavation and treatment, decontamination procedures for equipment and personnel, and storm water run-off and run-on controls. Incompatible hazardous chemicals used in the treatment process would be segregated during storage, and best management practices would be followed to prevent the uncontrolled release of chemicals to the environment.

It is estimated that 21 to 27 months would be required to complete remedial activities under Alternative 5, from the initiation of work plans to backfilling excavated areas and disposal of treatment residuals. Table 4-7 provides additional detail on the individual work elements involved in the execution of this alternative.

4.6.7 Implementability

Alkaline hydrolysis is a relatively new technology applied to NAC-contaminated soil, particularly using caustic soda. Based on available documentation, it has been implemented on a field pilot scale only at one site (Tetra Tech, 2008b). Alkaline hydrolysis is not effective for the treatment of PAHs. Composting of PAH-contaminated soil after alkaline hydrolysis treatment could reduce the concentrations of PAHs to RGs.

Windrow composting is a reliable technology, as it has been implemented at a number of remediation sites to treat soil contaminated with nitroaromatic explosives, PAHs, and other chemicals, such as pesticides. Composting technology has also been widely used in the treatment of agricultural wastes and the management of treatment residuals from municipal wastewater treatment plants. Equipment, personnel, and amendments are available locally.

Maectite stabilization has been used at numerous sites to immobilize lead in soil both as an in situ and ex situ technology. Equipment and personnel are available locally. The chemical stabilization reagent is available from Sevenson Environmental Services, Inc.

Compliance sampling of the sidewall and bottom areas of the excavation and analysis of the soil samples for COCs can be used to monitor the effectiveness of excavation in removing soil contaminated above RGs.

The effectiveness of the alkaline hydrolysis process is easily monitored in process by taking soil pH measurements using a field pH instrument. Sampling and analysis of the treated soil after caustic soda/ferric chloride treatment and neutralization would determine final compliance of the treated soil. The alkaline hydrolysis treated soil must pass TCLP for 2,4-DNT, remedial goals for all COCs (for on-site disposal), and alternative LDR treatment standards for underlying hazardous constituents in soil. As mentioned in Section 4.6.1, treatment with caustic soda may stabilize lead-contaminated soil such that it may pass TCLP. However, it would not reduce total lead concentrations with respect to meeting LDR treatment standards or remedial goals.

The effectiveness of the composting process is monitored by periodic sampling and analysis of the compost during and after the treatment process. Colorimetric field analytical methods would be utilized during precompliance testing to augment analytical work in off-site laboratories to lower analytical costs. Standard fixed-base laboratory analyses would be used for final compliance sampling after treatment was complete for each batch of compost. The treatment process could be extended for any composted material that fails compliance testing.

The chemically stabilized soil must pass TCLP for lead. All soil that is a hazardous waste upon excavation must comply with the alternative LDR treatment standards for underlying hazardous constituents in soil (see Table 2-11 in the 2003 FS for more information on requirements of the LDRs as they apply to TNTA). Under either of the treatment processes, treated soil could be reprocessed until compliance levels were met. Alternately, the treated soil could be disposed off site in a Subtitle C TSDF as a hazardous waste.

The alternative does not preclude additional remedial action for soil if needed.

Alternative 5 does not present any unusual regulatory requirements that would compromise the administrative feasibility of the remedial approach. OEPA would have to approve the disposal facility used for any waste materials managed off site.

4.6.8 Cost

The detailed cost evaluation for the implementation of Alternative 5 for TNTA is presented in Table 4-7. The estimated capital cost for Alternative 5 is $4.0 million.

A contingency of 30 percent has been added to the cost estimate to account for uncertainty in the estimated volume of soil requiring remediation and to provide an allowance for cost elements that are not identifiable at the present time. Due to the relatively short time frame over which the remedial alternative would be completed, all costs associated with its implementation are classified as capital costs. Accordingly, there are no O&M costs for this alternative, and the present value cost is equivalent to the capital cost.

4.6.9 State Acceptance

This criterion will be evaluated in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

4.6.10 Community Acceptance

This criterion will be evaluated in more detail in the decision document for the remedial action, after a public meeting has been conducted and the public comment period has concluded.

5.0 Comparative Analysis of Remedial Alternatives

This chapter provides a comparative analysis of all six alternatives developed in Chapter 4.0. The comparison will be based on the evaluation criteria and the overall feasibility of the alternatives in achieving RAOs for contaminated soil at TNTA. A summary of this comparative analysis is presented in Table 5-1.

5.1 Protection of Human Health and the Environment

All of the alternatives, with the exception of Alternative 1, would permanently treat/remove contaminated soil, thereby reducing cancer and noncancer human health risks to within the respective OEPA risk management ranges. Alternatives 2 through 5 may also benefit ecological receptors by significantly reducing the EHQs associated with soil contamination at the sites. Alternatives 2 through 5 may provide a corollary benefit to long-term groundwater and surface water quality by removing or mitigating the most significant source areas that contribute to contamination in these media. Alternative 1 does not employ removal, containment, or treatment response actions that would mitigate the impact of source areas on receptors or other environmental media.

5.2 Compliance with ARARs

All of the alternatives, with the exception of Alternative 1, would comply with the chemical-, location-, and action-specific ARARs. Location- and action-specific ARARs are not applicable to Alternative 1 because no action would be taken.

5.3 Long-Term Effectiveness and Permanence

All of the alternatives, with the exception of Alternative 1, would reduce the magnitude of residual risk at TNTA to levels within the risk management range. No long-term controls would be required at the site for Alternatives 2 though 5.

5.4 Reduction of the Toxicity, Mobility, or Volume of Contamination

Alternatives 2, 4, and 5 would satisfy the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances as their principal element. Alternatives 2, 4, and 5 would treat about 20 to 23 percent of the contaminated soil excavated from TNTA. Alternative 3 would not employ any on-site treatment, although off-site treatment of some contaminated soil would be required to comply with LDR requirements prior to disposal.

The composting component of Alternatives 2, 4, and 5 provides essentially irreversible treatment by coupling biodegradation and transformation processes to reduce the toxicity and mobility of NACs and to a lesser extent, PCBs in soil. The alkaline hydrolysis component of Alternative 5 provides irreversible treatment by chemically transforming NACs to less toxic compounds. The chemical stabilization component of Alternatives 4 and 5 reduces the mobility of lead. While chemical stabilization may not be an irreversible process, the combination of stabilization and off-site disposal at an approved landfill should prevent the lead in the treated soil from leaching back into the environment. Although Alternative 3 would remove contamination from the site, it would not result in any reduction of contaminant mass. The disposal of excavated soil in an appropriate TSDF would minimize the potential for contaminants to leach into the environment. Alternative 1 would have no effect on the toxicity, volume, or mobility of soil contamination.

5.5 Short-Term Effectiveness

Alternatives 2 through 5 would all provide adequate safeguards for site workers and the community during remediation. All the contaminated soil excavated under Alternatives 2 through 5 would require off-site management. Short-term effectiveness is not relevant to Alternative 1 because no action would be taken. No threatened or endangered animal or plant species will be significantly affected or destroyed by remedial actions at TNTA. In the event threatened and/or endangered plant species were later discovered in the proposed remediation areas, care would be taken to minimize disturbance. There would be short-term disturbances to ecological habitat as a result of the proposed remediation; however, the re-establishment of vegetative cover following the action would allow displaced species to recolonize these disturbed areas. Some of the treatment chemicals used in Alternative 5 are hazardous materials. Material handling systems must be designed to protect remediation workers from exposure to corrosive chemicals and best management practices should be used to prevent the release of hazardous materials to the environment.

Remedial durations for TNTA are presented in Table 5-1. All of the alternatives would be completed within approximately the same time frame. Alternative 3 would be completed within the shortest period of time (approximately 12 to 18 months), while Alternatives 2, 4, and 5 would require between 18 and 27 months to complete.

5.6 Implementability

All of the technologies in these alternatives, with the exception of Alternative 5, are well developed and have been implemented on a full-scale basis on numerous projects. The alkaline hydrolysis component of Alternative 5 has been successfully tested on a pilot scale. Equipment, technical specialists, and materials are available for all the alternatives. The effectiveness of the alternatives can be monitored by sampling and analysis. All of the alternatives would require the approval of OEPA for disposal of material off site. None of the alternatives would preclude additional actions if the technologies were not completely effective.

5.7 Cost

Alternative 1 is the lowest cost alternative. Alternative 5 has the lowest cost of all the alternatives that meet the threshold criteria of protection of human health and the environment and compliance with ARARs. The remaining alternatives are ranked from lowest to highest cost: Alternative 3, Alternative 4, and Alternative 2.

Remedial costs for TNTA are presented in Table 5-1.

5.8 State Acceptance

This criterion will be evaluated in a decision document for TNTA after receiving regulatory review comments on this FFS.

5.9 Community Acceptance

This criterion will be evaluated in a decision document for TNTA after a public meeting is held.

6.0 References

The following are new references. Please refer to the 2003 Final FFS for previously used references.

Brady, N.C., and Weil, R.R., 2002, ***The Nature and Properties of Soils, 13th Edition***, Prentice Hall, Upper Saddle River, New Jersey.

Tetra Tech, Inc., 2008a, ***Summary of Bench Scale and Field Treatability Tests, Chemical Treatment of TNT and DNT-Contaminated Soil, TNT Manufacturing Valley, Volunteer Army Ammunition Plant, Chattanooga, Tennessee***, prepared for the U.S. Army Corps of Engineers, Mobile District, January.

Tetra Tech, Inc., 2008b, ***Final Addendum to the Corrective Measures Implementation Work Plan for the TNT Manufacturing Valley (VAAP-32), Volunteer Army Ammunition Plant, Chattanooga, Tennessee, Soil Implementation Work Plan for Full-Scale Treatment, Chemical Treatment of TNT and DNT-Contaminated Soil***, prepared for the U.S. Army Corps of Engineers, Mobile District, January.

Shaw Environmental, Inc. (Shaw), 2003, ***TNT Areas A and C Remedial Investigation, Former Plum Brooks Ordnance Works, Sandusky, Ohio, Volume 4 – Focused Feasibility Study for Soil and Sediment, Final***, October.

TABLES

Table 2-8

Area and Volume of Contaminated Soil Requiring Remediation
Feasibility Study
TNT Area A, Former Plum Brook Ordnance Works
Sandusky, Ohio

Building No.	Building Name	Area No.	Area (ft^2)	Perimeter (feet)	Depth (feet)	Excavated Soil Volume (yd^3)	Excavated Soil Volume PCB>RG (yd^3)	Excavated Soil Volume Pb>RG (yd^3)	Total Soil Volume PCB/Pb (yd^3)	Volume Hazardous Waste 2,4-DNT[a] (yd^3)	Volume Hazardous Waste Lead[b] (yd^3)	Volume Hazardous Waste 2,4-DNT+Pb (yd^3)	Total Volume Hazardous Waste (yd^3)	Volume PCB Waste[c] (yd^3)	Figure No.[d]
112	Bi-Tri House	I	4444	268	9.5	1564	0	0	0	30	15	0	45	0	1-7
116	Wash House-Line 1	I	400	80	15	222	0	0	0	0	0	0	0	0	1-8
119	Acid & Fume Recovery	I	5376	374	9	1792	133	0	133	1792	187	187	1792	0	
		II	1854	231	4	275	0	275	275	0	275	0	275	0	
		Total	7230	605		2067	133	275	408	1792	462	187	2067	0	1-9
126	Wash House-Line 2	I	3600	240	11	1467	0	0	0	0	0	0	0	0	
		II	4505	347	8	1335	0	0	0	0	0	0	0	0	
		Total	8105	587		2802	0	0	0	0	0	0	0	0	1-10
129	Acid & Fume Recovery	I	400	80	7	104	0	0	0	52	0	0	52	0	1-11
131	Mono House	I	3600	240	13	1733	0	0	0	578	267	267	578	0	1-12
133	Fortifier House	I	400	80	6	89	0	0	0	0	0	0	0	0	1-13
139[b]	Acid & Fume Recovery	I	400	0	8	119	119	60	119	119	60	60	119	119	
		II	2835	316	4	420	0	420	420	0	420	0	420	0	
		Total	3235	316		539	119	480	539	119	480	60	539	119	1-14
141	Mono House	I	515	90	4	76	0	0	0	38	76	0	114	0	1-15
142	Bi-Tri House	I	1740	149	4	258	60	58	88	30	58	30	58	0	
		II	547	79	2	41	0	41	41	0	41	0	41	0	
		Total	2287	228		299	60	99	129	30	99	30	99	0	1-16
143	Fortifier House	I	266	64	7	69	0	0	0	0	0	0	0	0	
		II	280	67	7	73	0	0	0	0	0	0	0	0	
		III	400	80	7	104	0	0	0	0	0	0	0	0	
		Total	946	211		246	0	0	0	0	0	0	0	0	1-17 REV
146	Wash House-Line 4	I	7744	360	15	4302	0	0	0	143	0	0	143	0	1-18
148	Nailing House	I	296	60	7	77	0	0	0	0	0	0	0	0	1-19
182	Graining House	I	3600	240	7	933	0	0	0	533	0	0	533	0	1-3
187	Wastewater Settling Tanks/Pump House	I	1680	84	10	622	0	0	0	0	0	0	0	0	1-35 NEW
192	DNT Sweating/Graining House	I	3102	214	4	460	0	0	0	460	0	0	460	0	1-4
195	DNT Nitrating	I	3600	240	7	933	0	0	0	117	0	0	117	0	1-5
111	Mono House	I	400	80	6	89	0	0	0	30	0	0	30	0	1-6
Total			**51984**	**4063**		**17157**	**312**	**854**	**1076**	**3922**	**1399**	**544**	**4777**	**119**	

Notes:

= Estimated volume of soil that is co-contaminated with hazardous levels of both 2,4-DNT and lead.
= Estimated volume of Pb-contaminated soil that cannot be treated due to elevated levels of PCBs
= Estimated volume of NAC-contaminated soil that cannot be treated due to elevated levels of PCBs

Other volumes of note:

Lead minus PCB remediation waste: 1339 yd^3 (1399 yd^3 total lead minus 60 yd^3 PCB remediation waste)
Lead only: 855 yd^3 (1399 yd^3 total lead minus 544 yd^3 hazardous 2,4-DNT, includes PCB remediation waste)
2,4-DNT minus PCB remediation waste: 3803 yd^3 (3922 yd^3 total 2,4-DNT minus 119 yd^3 PCB remediation waste)
2,4-DNT only: 3319 yd^3 (3922 yd^3 total 2,4-DNT minus 544 yd^3 hazardous lead and minus additional 59 yd^3 PCB remediation waste not co-contaminated with lead)
Total hazardous waste minus PCB remediation waste: 4658 yd^3 (4777 yd^3 total hazardous minus 119 yd^3 PCB remediation waste)
Total nonhazardous waste waste: 12380 yd3 (17157 yd3 total total excavated minus 4777 yd3 total hazardous waste)

[a] Volume of soil with conc. of 2,4-DNT > 2.4 mg/kg (20X TCLP limit) .
[b] Volume of soil with conc. of lead > 200 mg/kg (150 mg/kg x 1.33 blending factor for composting). Factor of 1.33 is used because soil is projected to be approximately 75 weight percent of compost mixture. Therefore, lead in soil up to 200 mg/kg would be below the LDR limit after composting.
[c] Volume of soil with total PCBs > 50 mg/kg is classified as a bulk PCB remediation waste.
[d] "REV" indicates that the figure is revised and is part of this Addendum; "NEW" indicates that the figure is new and is part of this Addendum.

Table 3-1

Effectiveness of Lime Treatment on Soil Contaminated with Nitroaromatic Explosive Compounds
TNTA Manufacturing Area
Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	HTNT2[1] Untreated (mg/kg)	HTNT2[1] Treated[3] @ pH 11 (mg/kg)	HTNT2[1] Removal (%)	HTNT2[1] Treated[3] @ pH 12 (mg/kg)	HTNT2[1] Removal (%)	ELBP2[2] Untreated (mg/kg)	ELBP2[2] Treated[3] @ pH 11 (mg/kg)	ELBP2[2] Removal (%)	ELBP2[2] Treated[3] @ pH 12 (mg/kg)	ELBP2[2] Removal (%)
TNT	16109.8	1054.4	93	834.6	95	115.7	2.2	98	2.4	98
2,4-DNT	289.2	208.6	28	98.6	66	142.7	98.5	31	56.2	61
2,6-DNT	70.5	41.7	41	31.0	56	58.0	43.5	25	34.4	41
Total DNTs	359.7	250.3	30	129.6	64	200.7	142	29	90.6	55
2ADNT	66.7	27.3	59	14.3	79	0.7	1.0	**-43**	4.4	**-529**
4ADNT	80.3	41.2	49	22.4	72	0.5	2.0	**-300**	15.1	**-2920**
Total ADNTs	147.0	68.5	53	36.7	75	1.2	3.0	**-150**	19.5	**-1525**
TNB	24.2	65.9	**-172**	15.2	37	1.1	5.2	**-373**	nd	100

Notes:

[1] HTNT2 = soil from former ammunition plant, Hallschlag, Germany.

[2] ELBP2 = soil from burning grounds at former ammunition plant, Torgau/Elsnig, Germany.

[3] Treated by addition of $Ca(OH)_2$.

TNT - 2,4,6-Trinitrotoluene.
DNT - Dinitrotoluene.
2ADNT - 2-Amino-4,6-Dinitrotoluene.
4ADNT - 4-Amino-2,6-Dinitrotoluene.
TNB - 1,3,5-Trinitrobenzene.

Reference: Modified from Emmrich, M., 2001, "Kinetics of the Alkaline Hydrolysis of Important Nitroaromatic Co-contaminants of 2,4,6-Trinitrotoluene in Highly Contaminated Soils", ***Environmental Science and Technology*** , 35(5), 874-877.

Table 3-2

Partial Summary of VAAP Pilot Test Results for Alkaline Hydrolysis with Caustic Soda
TNTA Manufacturing Area
Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Units	PBOW TNTA MDC	TNTA Soil RG	20 X TCLP Limit	ATS for Soil	BS6		BS7		BS8	
						Initial Conc.	Final Conc.	Initial Conc.	Final Conc.	Initial Conc.	Final Conc.
2,4,6-Trinitrotoluene	mg/kg	530	8.0			8000 D	0.05 U	8000 D	0.05	8000 D	3.9
2,4-Dinitrotoluene	mg/kg	8912	6.0	2.6	1400	2900 D	0.52 P	2900 D	1.2	2900 D	0.63
2,6-Dinitrotoluene	mg/kg	10274	1.5		28	1800 D	**6.5 P**	1800 D	**3.2**	1800 D	**1.7**
Total Dinitrotoluenes	mg/kg		7.5			4700 D	7	4700 D	4.4	4700 D	2.4
1,3,5-Trinitrobenzene	mg/kg		-			49 JDP	0.05 U	49 JDP	0.05 U	49 JDP	0.05 U
1,3-Dinitrobenzene	mg/kg		-			50 UD	0.05 U	50 UD	0.05 U	50 UD	0.05 U
Nitrobenzene	mg/kg		-			50 UD	3.2 P	50 UD	3.9 P	50 UD	2.1 P
2-Nitrotoluene	mg/kg	582	31			50 UD	1.9 P	50 UD	3	50 UD	1.5 P
3-Nitrotoluene	mg/kg		-			50 UD	0.67 P	50 UD	1.7	50 UD	0.91
4-Nitrotoluene	mg/kg	484	9.0			50 UD	0.77 P	50 UD	1.4 P	50 UD	0.76
2-Amino-4,6-Dinitrotoluene	mg/kg	33.6	1.3			50 UD	0.05 U	50 UD	0.05 U	50 UD	0.05 U
4-Amino-2,6-Dinitrotoluene	mg/kg	16	1.7			50 UD	0.05 U	50 UD	0.05 U	50 UD	0.05 U
Nitrate	mg/kg		-			8.4	63 U	8.4	63 U	8.4	69 U
Nitrite	mg/kg		-			17.5	604	17.5	1110	17.5	1390
pH	mg/kg		-			7.5	13.4	7.5	13.1	7.5	13.2

Notes:
1. BSG6 = 16 oz NaOH per 10 pounds of soil
2. BSG7 = 10 oz NaOH + 200 mL $FeCl_3$ per 10 pounds of soil
3. BSG8 = 10 oz NaOH + 100 mL $FeCl_3$ per 10 pounds of soil

MDC = Maximum Detected Concentration in Soil
RG = Remedial Goal
TCLP = Toxic Characteristic Leaching Procedure
ATS = Alternate Treatment Standard
VAAP = Volunteer Army Ammunition Plant

Source: ***Summary of Bench Scale and Field Treatability Tests, Chemical Treatment of TNT- and DNT-Contaminted Soil, TNT Manufacturing Valley, Volunteer Army Ammunition Plant, Chattanooga, Tennessee*** ; prepared for the U.S. Army Corps of Engineers, Mobile District; prepared by Tetra Tech, Inc, Oak Ridge, Tennessee.

Table 3-3

Summary of Alkaline Hydrolysis Treatability Study Results
TNTA Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Treatment		**TNT**	**2,6-DNT**	**2,4-DNT**	**4A-2,6-DNT**	**2A-4,6-DNT**
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Max TNTC Conc.		12000	10274	8912	933	45.4
% Trt Conc > Limits						
RG		8	1.5	6.0	1.7	1.3
20X TCLP		-	-	2.6	-	-
Min ATS		-	280	1400	-	-
	pH					
After 7-day treatment						
Control[a]	7.80	2575[a]	11441[b]	10733[b]	11	4
Na_2CO_3	10.60	287	6916	6193	16	10
Na_2CO_3/Fe	10.60	305	8715	7834	8J	3J
Portland cement	11.55	21	11703	8867	8J	2J
Portland cement/Fe	11.48	67	10889	9025	7J	4J
NaOH	12.66	5	10055	344	10U	10U
NaOH/Fe	12.62	4	7783	282	4J	10U
CaO	12.02	1843	9809	7512	10	10U
CaO/Fe	12.02	3	9427	8002	7J	10U
Kiln. Dust	10.91	62	10415	7860	7J	3J
Kiln. Dust/Fe	10.96	89	9601	8711	7J	3J
Bed ash	12.00	92	10652	7911	7J	10U
Bed ash/Fe	12.00	23	9927	7710	7J	10U
After 14-day treatment						
Portland cement	NA	789	8446	7508	12.2	1.5J
Portland cement/Fe	NA	48	9877	7615	13.4	2.1J
NaOH	NA	1.8J	11182	127	6.9J	10U
NaOH/Fe	NA	1.9J	9256	67	6.9J	10U
CaO	NA	11	9948	8194	10.5	3.3J
CaO/Fe	NA	2.3J	9253	7486	9.8J	2.2J
Bed ash	NA	72	10290	7926	11	1.4J
Bed ash/Fe	NA	2.5	11149	7935	10.9	2J
After 28-day treatment						
Control	8.36	2191	9386	9560	8.6J	4.9J
Portland cement	11.27	103	9033	7020	8.5J	5 U
Portland cement/Fe	11.50	1	8392	6718	8.8J	5 U
NaOH	11.76	3	8452	35	6.4J	5 U
NaOH/Fe	11.89	0.8J	10667	17	4.5J	5 U
CaO/Fe	12.01	2.5 U	9691	6702	9.2J	5 U
Bed ash	11.84	4802	10085	6831	11.6	5 U
Bed ash/Fe	11.90	108	9850	6780	7J	5 U
After 40-day treatment						
Na_2CO_3	10.75	659	10005	9067	5	4
Na_2CO_3/Fe	10.77	408	9438	8113	6	5
Portland cement	NA	16	6826	5537	7	4 U
Portland cement/Fe	NA	2	9670	6414	9	4 U
NaOH	11.44	2 U	9744	35	5	4 U
NaOH/Fe	11.60	2 U	8931	12	3	4 U
CaO/Fe	NA	11	9378	6667	10	4 U
Bed ash	NA	27	10429	6390	8	4 U
Bed ash/Fe	NA	2 U	9851	6681	10	4 U

Table 3-3

Summary of Alkaline Hydrolysis Treatability Study Results
TNTA Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Notes:
TNT - 2,4,6-Trinitrotoluene.
2,6-DNT - 2,6-Dinitrotoluene.
2,4-DNT - 2,4-Dinitrotoluene.
4A-2,6-DNT - 4-Amino-2,6-dinitrotoluene.
2A-4,6-DNT - 2-Amino-4,6-dinitrotoluene.
Na_2CO_3 - Sodium carbonate.
Fe - Iron.
NaOH - Sodium hydroxide.
CaO - Calcium oxide.
RG - Remedial goal.
TCLP - Toxicity characteristic leaching procedure.
ATS - alternative land disposal restriction treatment standard for contaminated soil.
[a] Concentration in untreated soil sample.
[b] Spiked concentration in untreated soil sample.
U - Not detected.
J - Estimated value below laboratory reporting limit.

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative 2		**Site:**	TNT Area A
Excavation/Composting/Off-Site Disposal			Plum Brook Ordnance Works
Cost Estimate		**Date:**	**12/8/2008**

Scope:
1. Prepare composting work plan, H&S plan, materials list, and procurement along with the final report
2. Mobilize equipment and personnel.
3. Prepare site for remedial activity.
4. Excavate contaminated soil, perform confirmation sampling & characterize waste.
5. Treatment of soil contaminated with nitroaromatic compounds via windrow composting.
6. Off-site disposal of treated material.
7. Site restoration.
8. Demobilize equipment and personnel.

1.0 Work Plans and Procurement

Includes:
1. Labor to generate work plans, including engineering specifications and Health and Safety Plan, along with the Final Report.
2. Procure equipment and materials.

Service	Unit	Unit Cost		Subtotal	
Work Plans and Final Report	1	$15,000.00	/ls	$15,000.00	
Procurement	1	$10,000.00	/ls	$10,000.00	
				Subtotal	**$25,000.00**

2.0 Mobilization/Demobilization of Equipment and Personnel

Includes:
1. Mobilization and demobilization of local equipment and personnel.
2. Set-up/tear down office trailer.

Assumptions:
1. Labor and equipment are available locally.
2. Pressure washer to be purchased for use during project.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor/Equipment:					
Mobe/Demobe	1	$5,000.00	/ls	$5,000.00	
Office Trailer (set up/tear down)	1	$500.00	/ls	$500.00	
Pressure Washer	1	$500.00	/ls	$500.00	
				Subtotal	**$6,000.00**

3.0 Site Preparation

Includes:
1. Existing site can be used and no additional site preparation costs are required.

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil

Includes:
1. Excavation of soil with contaminants exceeding RGOs.
2. Screen oversize material.
3. Collect confirmatory samples to verify extent of excavation.
4. Staging and characterizing waste stream.

Assumptions and Calculations:

1. Cubic yards of consolidated soil excavated =	17157
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	22304
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	24535
6. Capacity of screening plant (tons/hr) =	100
7. Excavator: hydraulic backhoe, 1 cy bucket.	
8. Excavator output (cy/day) =	600
9. Days to excavate soil =	45
10. Dump truck capacity (cy) =	12
11. Dump truck haul distance (mi.) =	0.5
12. Dump truck output (cy/day) =	250
13. Number of required dump trucks per day =	2
14. Soil sample collected for waste characterization / cy =	300
15. Number of soil samples collected for waste characterization =	74
16. Number of excavation crew =	2
17. Number of screening crew =	3
18. Lineal foot of excavation per confirmation sample =	20
19. Resampling factor for confirmation sampling =	1.1
20. Number of confirmatory samples from excavated area =	366
21. Excavation area (ft^2) =	51984
22. Cost multiplier for 1-week turnaround on analytical data =	1.25
23. Fraction of excavation work performed in Level C PPE =	0.10
24. Labor productivity factor for Level C work =	0.67
25. Days excavation crew in Level C =	5
26. Days screening crew in Level C =	4
27. Perimeter of excavation area (ft) =	4063
28. Excavation area (sf) =	51984
29. Volume of pit water requiring offsite disposal (gal) =	20000

30. The excavation duration is 24 days yielding 1 month working the standard work week.

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	360	$49.00	/hr	$17,640.00
QA (Sampling) Coordinator	360	$36.00	/hr	$12,960.00
H&S Coordinator	360	$49.00	/hr	$17,640.00
Chemist (home office)	90	$51.00	/hr	$4,590.00
Equipment Operator	45	$406.00	/day	$18,270.00
Equipment Operator	35	$406.00	/day	$14,210.00
Equipment Operator	35	$406.00	/day	$14,210.00
Laborers	80	$341.60	/day	$27,328.00
Truck Drivers	90	$341.60	/day	$30,744.00

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil (continued)					
Equipment:					
Excavator	3	$4,000.00	/mo	$12,000.00	
100-ton/hr Screening Plant	7	$1,800.00	/wk	$12,600.00	
Radial Stacking Conveyor	7	$1,222.00	/wk	$8,554.00	
Dozer	2	$3,500.00	/mo	$6,125.00	
Dump Truck	3	$3,890.00	/mo	$11,670.00	
Dump Truck	3	$3,890.00	/mo	$11,670.00	
3000 gal. Water Truck	45	$402.00	/day	$18,090.00	
21,000 gal Frac Tank	14	$1,400.00	/mo	$19,600.00	
150 gpm Pump	3	$2,439.00	/ea.	$7,317.00	
300 gpm Pump	3	$3,749.00	/ea.	$11,247.00	
Office Trailer	3	$800.00	/mo	$2,400.00	
Porta Jon	3	$175.22	/mo	$525.66	
Generator	3	$170.35	/mo	$511.06	
P/U Truck	3	$1,800.00	/mo	$5,400.00	
Analytical:					
TCLP Extraction	74	$12.88	/ea	$952.75	
SVOCs (8270C)	440	$300.00	/ea	$132,000.00	
NACs (8330)	440	$197.50	/ea	$86,900.00	
Lead	440	$30.00	/ea	$13,200.00	
PCBs	440	$103.75	/ea	$45,650.00	
NAC field analyses	366	$40.00	/ea	$14,640.00	
Lead field analyses	3	$4,200.00	/mo.	$12,600.00	
Shipping	117	$40.00	/ea	$4,693.33	
Materials & Services:					
Level D PPE	173	$10.00	/day	$1,730.00	
Level C PPE	22	$35.00	/day	$770.00	
PID rental	3	$974.00	/mo.	$2,922.00	
CGI rental	3	$380.00	/mo.	$1,140.00	
Pit Water Disposal	20	$1.62	/kgal	$32.40	
				Subtotal	**$602,532.00**

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Windrow Composting of Contaminated of Soil

Includes:
1. Purchase of composting equipment.
2. Procurement & stockpiling of composting amendments.
3. Mix and compost soil and amendments.
4. Pre-compliance testing: after compost formation & at end of treatment.
5. Pre-compliance testing using definitive field analysis for NAC.

Assumptions:

1. Laydown area is 260' feet wide x 800 feet long.	
2. 75% of laydown area is available for windrows ad 25% is available for stockpiling amendments.	
3. Compost recipe is 25% soil, 2.9% agricultural amendment (manure) and 72.1% bulking amendment (straw).	
4. Widrows are spaced 5 feet apart from one another.	
5. There is a 35-foot space at each end of the windrow allotting for movement of the windrow turner.	
6. Duration per batch (wk) =	6
7. The windrows will be staggered by 1 week.	
8. Volume of consolidated soil to be treated, 2-4,DNT only (cy) =	3319
9. Swell factor for soil upon excavation =	1.3
10. Volume of unconsolidated soil to be treated (cy) =	4315
11. Compost treatment duration (weeks) =	21
12. Each windrow is 6 feet high x 16 feet wide x 530 feet long, trapezoidal configuration.	
13.. Capacity of windrow turner (tons/hr) =	3,200
14.. Operating life of flails (hrs) =	25
15. Number of flails on windrow turner =	172
16. Volume of compost per windrow (cy) =	1,178
17. Per windrow the soil volume is, at 25% (cy) =	294
18. Per windrow the manure volume is, at 2.9% (cy) =	34
19. Per windrow the straw volume is, at 72.1% (cy) =	849
20. Number of windrows =	15
21. Volume of manure (cy) =	512
22. Volume of straw (cy) =	12738
23. Compost additive volume correction factor =	0.8
24. Total volume of compost prior to treatment (cy) =	14,052
25. Bulk density of compost (tons/cy) =	0.368
26. Number of field crew =	6
27. Tractor and straw blower are in-use 1 day/week and on stand-by the rest of the week.	
28. Pre-compliance testing shall weekly per windrow and consist of:	
- EnSys TNT 20, one per batch. Number of samples =	90
- EnSys TNT 20, no. of samples per kit =	19
- Total NAC, one per batch. Number of samples =	90
29. Compliance testing shall be performed per windrow and upon compost treatment. Sampling shall consist of:	
- Total Semivolatiles. Number of samples =	15
- Total NACs. Number of samples =	15
-TCLP 2,4-DNT. Number of samples =	15
30. Standard work week is 7 days per week at 8 hours per day. Thus, assuming 30 working days per month.	

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Windrow Composting of Contaminated of Soil (continued)						
Service/Materials	**Unit**	**Unit Cost**		**Subtotal**		
Labor:						
Site Superintendent	1176	$49.00	/hr	$57,624.00		
QA (Sampling) Coordinator	1176	$36.00	/hr	$42,336.00		
H&S Coordinator	1176	$49.00	/hr	$57,624.00		
Windrow Turner Operator	147	$567.20	/day	$83,378.40		
Equipment Operator	147	$406.00	/day	$59,682.00		
Equipment Operator	147	$406.00	/day	$59,682.00		
Equipment Operator	147	$406.00	/day	$59,682.00		
Laborer	147	$341.60	/day	$50,215.20		
Environmental Tech	147	$200.00	/day	$29,400.00		
Equipment:						
Windrow Turner (6' x 19')	5	$45,000.00	/mo	$225,000.00		
Dozer	5	$3,500.00	/mo	$17,500.00		
Excavator	5	$4,000.00	/mo	$20,000.00		
Wheel Loader	5	$5,000.00	/mo	$25,000.00		
Tractor	168	$50.00	/hr	$8,400.00	In-use	
Tractor	1008	$30.00	/hr	$30,240.00	Stand-by	
Straw Blower	168	$40.00	/hr	$6,720.00	In-use	
Straw Blower	1008	$20.00	/hr	$20,160.00	Stand-by	
21000 gallon Frac Tank	5	$1,400.00	/mo	$7,000.00		
21000 gallon Frac Tank	5	$1,400.00	/mo	$7,000.00		
Trash/Pump Hose	1	$3,749.00	/ea	$3,749.00		
Office Trailer	5	$800.00	/mo	$4,000.00		
Porta Jon	5	$175.22	/mo	$876.10		
Generator	5	$170.35	/mo	$851.76		
P/U Truck	5	$1,800.00	/mo	$9,000.00		
Spectrophotometer	1	$3,012.00	/ls	$3,012.00		
Materials:						
Repl. Flails for Windrow Turner	14104	$9.50	/ea	$133,988.00		
Straw	12738	$11.25	/cy	$143,298.75		
Manure	512	$25.00	/cy	$12,808.33		
Water	1027	$9.40	/kgal	$9,653.80		
Level C PPE	882	$35.00	/day	$30,870.00		
Air Monitoring Screening Kits	1	$2,500.00	/ls	$2,500.00		
Moisture/Temp Probes	1	$700.00	/ea	$700.00		
Analytical:						
Pre-Compliance Sampling:						
EnSys Kit (TNT 20)	5	$572.00	/ea	$2,860.00		
- 19 samples per kit						
Total NACs	90	$145.00	/ea	$13,050.00		
Compliance Sampling:						
TCLP Semivolatiles	15	$175.00	/ea	$2,625.00		
Total NACs	15	$145.00	/ea	$2,175.00		
TCLP 2,4-DNT	15	$175.00	/ea	$2,625.00		
					Subtotal	**$1,245,286.00**

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Off-Site Disposal

Includes:
1. Dispose of stabilized soil and non-hazardous soil (not stabilized) at a non-hazardous waste
2. Dispose of treated compost at a non-hazardous landfill.
3. Dispose of PCB waste at a TSCA approved landfill.
4. Compliance sampling and analysis for off-site waste disposal.

Assumptions and Calculations:

1. Consolidated volume of D008 soil for haz disposal (cy) =	855	Soil haz Pb only
2. Consolidated volume of D030 soil for haz disposal (cy) =	603	Soil haz 2,4DNT+Pb or 2,4DNT+PCBs
3. Consolidated volume of total PCB contaminated soil (cy) =	0	Soil haz for PCBs+Pb only
4. Total consolidated soil for haz disposal (cy) =	1458	
5. Total volume unconsolidated soil for haz disposal (cy) =	1895	
6. Consolidated volume of untreated soil (cy) =	12380	
7. Unconsolidated volume untreated soil (cy) =	16094	
8. Weight of untreated soil (tons) =	17703	
9.Volume of compost, non-haz disposal (cy) =	14052	
10. Bulk density of compost (tons/cy) =	0.368	
11. Weight of treated compost, non-haz waste (ton) =	5171	
12. Total unconsol volume of non-haz waste for disposal (cy) =	30146	
13. Total weight of non-haz waste for disposal (tons) =	22874	
14. Non-haz waste transportation cost ($/hr) =	72	
15. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
16. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
17. Haz waste transportation cost ($/ton) =	35	
18. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
19. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
20. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
21. Haz waste regulatory fees ($/ton) =	10	
22. Number of crew =	3	
23. Load capacity of a 20 ton truck (tons) =	15	
24. Round trip travel time to non-haz waste landfill (hr) =	1	
25. Loads of non-haz waste or trips (hrs) =	1525	
26. Output of front-end loader (cy/day) =	550	
27. No. of wheel loaders =	2	
28. Number of field days =	30	
29. No. of truckloads of stormwater for disposal =	4	
30. Volume of stormwater per truckload (gal) =	4000	
31. Volume of stormwater requiring off-site disposal (gal) =	16000	
32. Stormwater shall be analyzed for TCLP semivolatiles prior to transport.		
33. At one sample per truckload, number of samples (ea) =	4	
34. Excavated soil is staged in 500 ton piles.		
35. One 10-point composite sample shall be collected from each 500-ton pile as part of compliance testing.		
36. Standard work week is 5 days per week at 8 hours per day.		

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Off-Site Disposal (continued)					
Service/Materials	**Unit**	**Unit Cost**		**Subtotal**	
Labor:					
Site Superintendent	240	$49.00	/hr	$11,760.00	
QA Coordinator	240	$36.00	/hr	$8,640.00	
H&S Coordinator	240	$49.00	/hr	$11,760.00	
Equipment Operator	30	$406.00	/day	$12,180.00	
Equipment Operator	30	$406.00	/day	$12,180.00	
Oiler	30	$293.00	/day	$8,790.00	
Materials:					
Level D PPE	90	$10.00	/day	$900.00	
Equipment:					
Wheel Loader	1.4	$5,000.00	/mo	$7,000.00	
Wheel Loader	1.4	$5,000.00	/mo	$7,000.00	
Office Trailer	1.4	$800.00	/mo	$1,120.00	
Porta Jon	1.4	$175.22	/mo	$245.31	
Generator	1.4	$170.35	/mo	$238.49	
P/U Truck	1.4	$1,800.00	/mo	$2,520.00	
Disposal Costs:					
Transportation (Non-Haz Waste)	1525	$72.00	/hr	$109,800.00	truck & driver
Disposal Cost (Non-Haz waste)	22874	$24.50	/ton	$560,423.97	Erie County Landfill
Transportation (Haz Waste)	2085	$35.00	/ton	$72,972.90	
Disposal Cost (D008 haz waste)	1223	$85.00	/ton	$103,925.25	
Disposal Cost (D030 haz waste)	862	$160.00	/ton	$137,966.40	
Disposal Cost (PCB haz waste)	0	$85.00	/ton	$0.00	
Stormwater Disposal	30	$0.25	/gal	$7.50	Enviro-Tank Clean
Analytical:					
Compliance Sampling:					
TCLP SVOC/NAC/metals	38	$400.00	/ea	$15,140.84	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$1,085,271.00**

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

7.0 Site Restoration

Includes:
1. Backfill excavated areas with clean backfill.
2. Re-seed site.
3. Perform road repair.

Assumptions and Calculations:

1. Volume of consolidated soil excavated (cy) =	17157
2. Compaction factor =	1.15
3. Volume of soil required for backfill (cy) =	19731
4. Cost of clean backfill soil delivered to site ($/cy) =	12
5. Output of front-end loader (cy/day) =	550
6. Field days required to backfill soil =	36
7. Number of field crew =	3

8. Upon completion of remedial action soil samples shall be taken within the laydown area to determine if any soil removal is required.
9. The laydown area shall be divided into 4 quarters and a 5-point composite collected (4 samples total).

10. Number of soil samples (ea) =	4

11. Allow 1 week for reseeding site and road repair.

12. Task duration (days) =	41

13. Standard work week is 5 days per week at 8 hours per day.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	328	$49.00	/hr	$16,072.00	
QA Coordinator	328	$36.00	/hr	$11,808.00	
H&S Coordinator	328	$49.00	/hr	$16,072.00	
Equipment Operator	36	$406.00	/day	$14,616.00	
Equipment Operator	36	$406.00	/day	$14,616.00	
Laborer	36	$341.60	/day	$12,297.60	
Reseeding	1	$5,000.00	/area	$5,000.00	
Road Repair	1	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	2	$3,500.00	/mo	$7,000.00	
Wheel Loader	2	$5,000.00	/mo	$10,000.00	
Office Trailer	2	$800.00	/mo	$1,600.00	
Porta Jon	2	$175.22	/mo	$350.44	
Generator	2	$170.35	/mo	$340.70	
P/U Truck	2	$1,800.00	/mo	$3,600.00	
Material:					
Backfill	19731	$12.00	/cy	$236,766.60	delivered to site
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Level D PPE	123	$10.00	/day	$1,230.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$530,517.00**

Table 4-1

Alternative 2 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

8.0 Overall Cost		
	Total Capital Cost	**$3,494,606.00**
	Contingency (30%)	**$1,048,382.00**
	PM Multiplier (7.5%)	**$262,095.00**
	Fee/Profit (10%)	**$349,461.00**
	Total Cost	**$5,155,000.00**

*This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative 3	**Site:**	TNT Area A
Excavation/Off-Site Disposal Cost Estimate		Plum Brook Ordnance Works
	Date:	**12/8/2008**

Scope:
1. Prepare work plan, H&S plan, materials list, and procurement along with the final report
2. Mobilize/demobilize equipment and personnel.
3. Prepare site for remedial activity.
4. Excavate contaminated soil, perform confirmation sampling & characterize waste.
5. Off-site disposal.
6. Site restoration.
7. Demobilize equipment and personnel.

1.0 Work Plans and Procurement

Includes:
1. Labor to generate work plans, including engineering specifications and Health and Safety Plan, along with the Final Report.
2. Procure equipment and materials.

Service	Unit	Unit Cost		Subtotal	
Work Plans and Final Report	1	$15,000.00	/ls	$15,000.00	
Procurement	1	$10,000.00	/ea	$10,000.00	
				Subtotal	**$25,000.00**

2.0 Mobilization/Demobilization of Equipment and Personnel

Includes:
1. Mobilization and demobilization of local equipment and personnel.
2. Set-up/tear down office trailer.

Assumptions:
1. Labor and equipment are available locally.
2. Pressure washer to be purchased for use during project.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor/Equipment:					
Mobe/Demobe	1	$5,000.00	/ls	$5,000.00	
Office Trailer (set up/tear down)	1	$500.00	/ls	$500.00	
Pressure Washer	1	$500.00	/ls	$500.00	
				Subtotal	**$6,000.00**

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

3.0 Site Preparation

Includes:

1. Delineate the laydown area, approximately 5 acres (800 feet long by 260 feet wide).
2. Clear laydown area.
3. Grade site for a 2% slope aiding in stormwater control.
4. Construct 12" erosion control berm around laydown area. Perimeter (ft)= 2120
5. Excavate soil for contact water retention pond (260 feet long by 30 feet wide by 3 feet deep).
6. Install 60-mil liner along retention pond.

Assumptions:

1. Survey Crew for delineation of the laydown area. The cost includes all survey area and is a lump sum cost.
2. Volume of con. soil excavated for contact water retention pond (cy) = 867
3. Swell factor for soil upon excavation = 1.3
4. Volume of unconsolidated soil for contact water retention pond (cy) = 1,127
5. Equipment for excavation; excavator: hydraulic backhoe, 1 cy bucket and roller.
6. Excavator output (cy/day) = 600
7.. Days to excavate soil = 3
8. Erosion control berm shall be along the site perimeter and to include silt fence and straw bales.
9. Volume of containment berm (cy) = 157
10. Duration (weeks): 2
11. Standard work week is 5 days per week at 8 hours per day. Thus, assuming 22 working days per month.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	80	$49.00	/hr	$3,920.00	
QA Coordinator	80	$36.00	/hr	$2,880.00	
Equipment Operator	10	$406.00	/day	$4,060.00	
Equipment Operator	10	$406.00	/day	$4,060.00	
Laborer	10	$341.60	/day	$3,416.00	
Laborer	10	$341.60	/day	$3,416.00	
Surveying	1	$24,000.00	/ls	$24,000.00	
Site Clearing	5	$2,300.00	/acre	$11,500.00	
60-mil Polymeric Liner (installed)	9540	$3.09	/sf	$29,436.62	
Equipment:					
Roller	80	$55.00	/hr	$4,400.00	
Excavator	1	$4,000.00	/mo	$4,000.00	
Office Trailer	1	$800.00	/mo	$800.00	
Porta Jon	1	$175.22	/mo	$175.22	
Generator	1	$170.35	/mo	$170.35	
P/U Truck	1	$1,800.00	/mo	$1,800.00	
Materials:					
Earthen Containment Berm	157	$6.00	/cy	$942.00	
Silt Fence	2120	$1.50	/lf	$3,180.00	
2' x 2' x 3' Straw Bales (delivered)	1060	$5.00	/ea	$5,300.00	
				Subtotal	**$107,456.00**

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil

Includes:
1. Excavation of soil with contaminants exceeding RGOs.
2. Screen oversize material.
3. Collect confirmatory samples to verify extent of excavation.
4. Staging and characterizing waste stream.

Assumptions and Calculations:

1. Cubic yards of consolidated soil excavated =	17157
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	22304
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	24535
6. Capacity of screening plant (tons/hr) =	100
7. Excavator: hydraulic backhoe, 1 cy bucket.	
8. Excavator output (cy/day) =	600
9. Days to excavate soil =	45
10. Dump truck capacity (cy) =	12
11. Dump truck haul distance (mi.) =	0.5
12. Dump truck output (cy/day) =	250
13. Number of required dump trucks per day =	2
14. Soil sample collected for waste characterization / cy =	300
15. Number of soil samples collected for waste characterization =	74
16. Number of excavation crew =	2
17. Number of screening crew =	3
18. Lineal foot of excavation per confirmation sample =	20
19. Resampling factor for confirmation sampling =	1.1
20. Number of confirmatory samples from excavated area =	366
21. Excavation area (ft^2) =	51984
22. Cost multiplier for 1-week turnaround on analytical data =	1.25
23. Fraction of excavation work performed in Level C PPE =	0.10
24. Labor productivity factor for Level C work =	0.67
25. Days excavation crew in Level C =	5
26. Days screening crew in Level C =	4
27. Perimeter of excavation area (ft) =	4063
28. Excavation area (sf) =	51984
29. Volume of pit water requiring offsite disposal (gal) =	20000

30. The excavation duration is 24 days yielding 1 month working the standard work week.

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	360	$49.00	/hr	$17,640.00
QA (Sampling) Coordinator	360	$36.00	/hr	$12,960.00
H&S Coordinator	360	$49.00	/hr	$17,640.00
Chemist (home office)	90	$51.00	/hr	$4,590.00
Equipment Operator	45	$406.00	/day	$18,270.00
Equipment Operator	35	$406.00	/day	$14,210.00
Equipment Operator	35	$406.00	/day	$14,210.00
Laborers	80	$341.60	/day	$27,328.00
Truck Drivers	90	$341.60	/day	$30,744.00

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil (continued)					
Equipment:					
Excavator	3	$4,000.00	/mo	$12,000.00	
100-ton/hr Screening Plant	7	$1,800.00	/wk	$12,600.00	
Radial Stacking Conveyor	7	$1,222.00	/wk	$8,554.00	
Dozer	2	$3,500.00	/mo	$6,125.00	
Dump Truck	3	$3,890.00	/mo	$11,670.00	
Dump Truck	3	$3,890.00	/mo	$11,670.00	
3000 gal. Water Truck	45	$402.00	/day	$18,090.00	
21,000 gal Frac Tank	14	$1,400.00	/mo	$19,600.00	
150 gpm Pump	3	$2,439.00	/ea.	$7,317.00	
300 gpm Pump	3	$3,749.00	/ea.	$11,247.00	
Office Trailer	3	$800.00	/mo	$2,400.00	
Porta Jon	3	$175.22	/mo	$525.66	
Generator	3	$170.35	/mo	$511.06	
P/U Truck	3	$1,800.00	/mo	$5,400.00	
Analytical:					
TCLP Extraction	74	$12.88	/ea	$952.75	
SVOCs (8270C)	440	$300.00	/ea	$132,000.00	
NACs (8330)	440	$197.50	/ea	$86,900.00	
Lead	440	$30.00	/ea	$13,200.00	
PCBs	440	$103.75	/ea	$45,650.00	
NAC field analyses	366	$40.00	/ea	$14,640.00	
Lead field analyses	3	$4,200.00	/mo.	$12,600.00	
Shipping	117	$40.00	/ea	$4,693.33	
Materials & Services:					
Level D PPE	173	$10.00	/day	$1,730.00	
Level C PPE	22	$35.00	/day	$770.00	
PID rental	3	$974.00	/mo.	$2,922.00	
CGI rental	3	$380.00	/mo.	$1,140.00	
Pit Water Disposal	20	$1.62	/kgal	$32.40	
				Subtotal	**$602,532.00**

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Off-Site Disposal

Includes:
1. Dispose of stabilized soil and non-hazardous soil (not stabilized) at a non-hazardous waste
2. Dispose of treated compost at a non-hazardous landfill.
3. Dispose of PCB waste at a TSCA approved landfill.
4. Analysis for off-site waste disposal.

Assumptions and Calculations:

1. Volume of consolidated, non-hazardous soil (cy) =	12380	
2. Volume of unconsolidated, non-hazardous soil (cy) =	16094	
3. Tons of non-hazardous soil for disposal =	17703	
4. Total consolidated volume of hazardous soil (cy) =	4777	
5. Consolidated volume of D008 soil for haz disposal (cy) =	855	Soil haz PB only
6. Consolidated volume of D030 soil for haz disposal (cy) =	3922	Soil haz 2,4-DNT
7. Consolidated volume of PCB soil for haz disposal (cy) =	0	Soil haz PCB+Pb (no DNT)
8. Total volume of unconsolidated hazardous soil (cy) =	6210	
9. Non-haz waste transportation cost ($/hr) =	72	
10. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
11. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
12. Haz waste transportation cost ($/ton) =	35	
13. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
14. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
15. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
16. Haz waste regulatory fees ($/ton) =	10	
17. Number of crew =	3	
18. Load capacity of a 20 ton truck (tons) =.	15	
19. Travel duration (round trip) to non-haz landfill (hrs) =	1	
20. Loads of non-haz waste or trips (hrs) =	1181	
21. Output of front-end loader (cy/day) =	550	
22. No. of wheel loaders =	2	
23. Number of field days =	21	
24. Standby time for haz waste disposal (approvals) =	12	
25. Total number of days in field (incl standby) =	33	
26. Four (4) truckloads of stormwater requiring off-site disposal.		
27. 4000 gallons of stormwater per truckload.		
28. Volume of stormwater requiring off-site disposal (gal) =	16000	
29. Stormwater shall be analyzed for TCLP semivolatiles prior to transport.		
30. At one sample per truckload, number of samples (ea) =	4	
31. Excavated soil is staged in 500 ton piles.		
32. One 10-point composite sample shall be collected from each 500-ton pile as part of compliance testing.		
33. Standard work week is 5 days per week at 8 hours per day.		

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	264	$49.00	/hr	$12,936.00
QA Coordinator	264	$36.00	/hr	$9,504.00
H&S Coordinator	264	$49.00	/hr	$12,936.00
Equipment Operator	33	$406.00	/day	$13,398.00
Equipment Operator	33	$406.00	/day	$13,398.00
Oiler	33	$293.00	/day	$9,669.00
Materials:				
Level D PPE	99	$10.00	/day	$990.00

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Off-Site Disposal (continued)					
Equipment:					
Wheel Loader	1.5	$5,000.00	/mo	$7,500.00	
Wheel Loader	1.5	$5,000.00	/mo	$7,500.00	
Office Trailer	1.5	$800.00	/mo	$1,200.00	
Porta Jon	1.5	$175.22	/mo	$262.83	
Generator	1.5	$170.35	/mo	$255.53	
P/U Truck	1.5	$1,800.00	/mo	$2,700.00	
Disposal Costs:					
Transportation (Non-Haz Waste)	1181	$72.00	/hr	$85,032.00	truck & driver
Disposal Cost (Non-Haz waste)	17703	$24.50	/ton	$433,733.30	Erie County Landfill
Transportation (Haz Waste)	6831	$35.00	/ton	$239,088.85	
Disposal Cost (D008 haz waste)	1223	$85.00	/ton	$103,925.25	
Disposal Cost (D030 haz waste)	5608	$160.00	/ton	$897,353.60	
Disposal Cost (PCB haz waste)	0	$85.00	/ton	$0.00	
Stormwater Disposal	16000	$0.25	/gal	$4,000.00	Enviro-Tank Clean
Analytical:					
Compliance Sampling:					
TCLP SVOC/NAC/metals	49	$400.00	/ea	$19,627.61	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$1,875,710.00**

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Site Restoration

Includes:
1. Backfill excavated areas with clean backfill.
2. Re-seed site.
3. Perform road repair.

Assumptions and Calculations:

1. Volume of consolidated soil excavated (cy) =	18024
2. Compaction factor =	1.15
3. Volume of soil required for backfill (cy) =	20727
4. Cost of clean backfill soil delivered to site ($/cy) =	12
5. Output of front-end loader (cy/day) =	550
6. Field days required to backfill soil =	38
7. Number of field crew =	3

8. Upon completion of remedial action soil samples shall be taken within the laydown area to determine if any soil removal is required.
9. The laydown area shall be divided into 4 quarters and a 5-point composite collected (4 samples total).

10. Number of soil samples (ea) =	4

11. Allow 1 week for reseeding site and road repair.

12. Task duration (days) =	43

13. Standard work week is 5 days per week at 8 hours per day.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	344	$49.00	/hr	$16,856.00	
QA Coordinator	344	$36.00	/hr	$12,384.00	
H&S Coordinator	344	$49.00	/hr	$16,856.00	
Equipment Operator	38	$406.00	/day	$15,428.00	
Equipment Operator	38	$406.00	/day	$15,428.00	
Laborer	38	$341.60	/day	$12,980.80	
Reseeding	1	$5,000.00	/area	$5,000.00	
Road Repair	1	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	2	$3,500.00	/mo	$7,000.00	
Wheel Loader	2	$5,000.00	/mo	$10,000.00	
Office Trailer	2	$800.00	/mo	$1,600.00	
Porta Jon	2	$175.22	/mo	$350.44	
Generator	2	$170.35	/mo	$340.70	
P/U Truck	2	$1,800.00	/mo	$3,600.00	
Material:					
Backfill	20727	$12.00	/cy	$248,726.60	delivered to site
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Level D PPE	129	$10.00	/day	$1,290.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$546,989.00**

Table 4-3

Alternative 3 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

7.0 Overall Cost		
	Total Capital Cost	**$3,163,687.00**
	Contingency (30%)	**$949,106.00**
	PM Multiplier (7.5%)	**$237,277.00**
	Fee/Profit (10%)	**$316,369.00**
	Total Cost	**$4,666,000.00**

*This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative 4	**Site:** TNT Area A
Excavation/Composting/Stabilization/Off-Site Disposal	Plum Brook Ordnance Works
Cost Estimate	**Date: 12/8/2008**

Scope:
1. Prepare composting work plan, H&S plan, materials list, and procurement along with the final report
2. Mobilize equipment and personnel.
3. Prepare site for remedial activity.
4. Excavate contaminated soil, perform confirmation sampling & characterize waste.
5. Treatment of soil contaminated with nitroaromatic compounds via windrow composting.
6. Chemically stabilize soil that is hazardous based on lead TCLP.
7. Off-site disposal.
8. Site restoration.
9. Demobilize equipment and personnel.

1.0 Work Plans and Procurement

Includes:
1. Labor to generate work plans, including engineering specifications and Health and Safety Plan, along with the Final Report.
2. Procure equipment and materials.

Service	Unit	Unit Cost		Subtotal	
Work Plans and Final Report	1	$15,000.00	/ls	$15,000.00	
Procurement	1	$10,000.00	/ea	$10,000.00	
				Subtotal	**$25,000.00**

2.0 Mobilization/Demobilization of Equipment and Personnel

Includes:
1. Mobilization and demobilization of local equipment and personnel.
2. Set-up/tear down office trailer.

Assumptions:
1. Labor and equipment are available locally.
2. Pressure washer to be purchased for use during project.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor/Equipment:					
Mobe/Demobe	1	$5,000.00	/ls	$5,000.00	
Office Trailer (set up/tear down)	1	$500.00	/ls	$500.00	
Pressure Washer	1	$500.00	/ls	$500.00	
				Subtotal	**$6,000.00**

3.0 Site Preparation

Includes:
1. Existing site can be used and no additional site preparation costs are required.

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil

Includes:

1. Excavation of soil with contaminants exceeding RGOs.
2. Screen oversize material.
3. Collect confirmatory samples to verify extent of excavation.
4. Staging and characterizing waste stream.

Assumptions and Calculations:

1. Cubic yards of consolidated soil excavated =	17157
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	22304
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	24535
6. Capacity of screening plant (tons/hr) =	100
7. Excavator: hydraulic backhoe, 1 cy bucket.	
8. Excavator output (cy/day) =	600
9. Days to excavate soil =	45
10. Dump truck capacity (cy) =	12
11. Dump truck haul distance (mi.) =	0.5
12. Dump truck output (cy/day) =	250
13. Number of required dump trucks per day =	2
14. Soil sample collected for waste characterization / cy =	300
15. Number of soil samples collected for waste characterization =	74
16. Number of excavation crew =	2
17. Number of screening crew =	3
18. Lineal foot of excavation per confirmation sample =	20
19. Resampling factor for confirmation sampling =	1.1
20. Number of confirmatory samples from excavated area =	366
21. Excavation area (ft^2) =	51984
22. Cost multiplier for 1-week turnaround on analytical data =	1.25
23. Fraction of excavation work performed in Level C PPE =	0.10
24. Labor productivity factor for Level C work =	0.67
25. Days excavation crew in Level C =	5
26. Days screening crew in Level C =	4
27. Perimeter of excavation area (ft) =	4063
28. Excavation area (sf) =	51984
29. Volume of pit water requiring offsite disposal (gal) =	20000

30. The excavation duration is 24 days yielding 1 month working the standard work week.

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	360	$49.00	/hr	$17,640.00
QA (Sampling) Coordinator	360	$36.00	/hr	$12,960.00
H&S Coordinator	360	$49.00	/hr	$17,640.00
Chemist (home office)	90	$51.00	/hr	$4,590.00
Equipment Operator	45	$406.00	/day	$18,270.00
Equipment Operator	35	$406.00	/day	$14,210.00
Equipment Operator	35	$406.00	/day	$14,210.00
Laborers	80	$341.60	/day	$27,328.00
Truck Drivers	90	$341.60	/day	$30,744.00

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil (continued)					
Equipment:					
Excavator	3	$4,000.00	/mo	$12,000.00	
100-ton/hr Screening Plant	7	$1,800.00	/wk	$12,600.00	
Radial Stacking Conveyor	7	$1,222.00	/wk	$8,554.00	
Dozer	2	$3,500.00	/mo	$6,125.00	
Dump Truck	3	$3,890.00	/mo	$11,670.00	
Dump Truck	3	$3,890.00	/mo	$11,670.00	
3000 gal. Water Truck	45	$402.00	/day	$18,090.00	
21,000 gal Frac Tank	14	$1,400.00	/mo	$19,600.00	
150 gpm Pump	3	$2,439.00	/ea.	$7,317.00	
300 gpm Pump	3	$3,749.00	/ea.	$11,247.00	
Office Trailer	3	$800.00	/mo	$2,400.00	
Porta Jon	3	$175.22	/mo	$525.66	
Generator	3	$170.35	/mo	$511.06	
P/U Truck	3	$1,800.00	/mo	$5,400.00	
Analytical:					
TCLP Extraction	74	$12.88	/ea	$952.75	
SVOCs (8270C)	440	$300.00	/ea	$132,000.00	
NACs (8330)	440	$197.50	/ea	$86,900.00	
Lead	440	$30.00	/ea	$13,200.00	
PCBs	440	$103.75	/ea	$45,650.00	
NAC field analyses	366	$40.00	/ea	$14,640.00	
Lead field analyses	3	$4,200.00	/mo.	$12,600.00	
Shipping	117	$40.00	/ea	$4,693.33	
Materials & Services:					
Level D PPE	173	$10.00	/day	$1,730.00	
Level C PPE	22	$35.00	/day	$770.00	
PID rental	3	$974.00	/mo.	$2,922.00	
CGI rental	3	$380.00	/mo.	$1,140.00	
Pit Water Disposal	20	$1.62	/kgal	$32.40	
				Subtotal	**$602,532.00**

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Windrow Composting of Contaminated of Soil

Includes:
1. Purchase of composting equipment.
2. Procurement & stockpiling of composting amendments.
3. Mix and compost soil and amendments.
4. Pre-compliance testing: after compost formation & at end of treatment.
5. Pre-compliance testing using definitive field analysis for NAC.

Assumptions:

1. Laydown area is 260' feet wide x 800 feet long.		
2. 75% of laydown area is available for windrows ad 25% is available for stockpiling amendments.		
3. Compost recipe is 25% soil, 2.9% agricultural amendment (manure) and 72.1% bulking amendment (straw).		
4. Widrows are spaced 5 feet apart from one another.		
5. There is a 35-foot space at each end of the windrow allotting for movement of the windrow turner.		
6. Duration per batch (wk) =	6	
7. The windrows will be staggered by 1 week.		
8. Volume of consolidated soil to be treated (cy) =	3803	Soil haz 2,4-DNT but not PCB
9. Swell factor for soil upon excavation =	1.3	
10. Volume of unconsolidated soil to be treated (cy) =	4944	
11. Compost treatment duration (weeks) =	23	
12. Each windrow is 6 feet high x 16 feet wide x 530 feet long, trapezoidal configuration.		
13.. Capacity of windrow turner (tons/hr) =	3,200	
14.. Operating life of flails (hrs) =	25	
15. Number of flails on windrow turner =	172	
16. Volume of compost per windrow (cy) =	1,178	
17. Per windrow the soil volume is, at 25% (cy) =	294	
18. Per windrow the manure volume is, at 2.9% (cy) =	34	
19. Per windrow the straw volume is, at 72.1% (cy) =	849	
20 . Number of windrows (ea) =	17	
21. Volume of manure (cy) =	581	
22. Volume of straw (cy) =	14436	
23. Compost additive volume correction factor =	0.8	
24. Total volume of compost prior to treatment (cy) =	15,968	
25. Bulk density of compost (tons/cy) =	0.368	
26. Number of field crew =	6	
27. Tractor and straw blower are in-use 1 day/week and on stand-by the rest of the week.		
28. Pre-compliance testing shall weekly per windrow and consist of:		
- EnSys TNT 20, one per batch. Number of samples =	102	
- EnSys TNT 20, no. of samples per kit =	19	
- Total NAC, one per batch. Number of samples =	102	
29. Compliance testing shall be performed per windrow and upon compost treatment. Sampling shall consist of:		
- Total Semivolatiles. Number of samples =	17	
- Total NACs. Number of samples =	17	
-TCLP 2,4-DNT. Number of samples =	17	
30. Standard work week is 7 days per week at 8 hours per day. Thus, assuming 30 working days per month.		

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Windrow Composting of Contaminated of Soil (continued)							
Service/Materials	Unit	Unit Cost		Subtotal			
Labor:							
Site Superintendent	1288	$49.00	/hr	$63,112.00			
QA (Sampling) Coordinator	1288	$36.00	/hr	$46,368.00			
H&S Coordinator	1288	$49.00	/hr	$63,112.00			
Windrow Turner Operator	161	$567.20	/day	$91,319.20			
Equipment Operator	161	$406.00	/day	$65,366.00			
Equipment Operator	161	$406.00	/day	$65,366.00			
Equipment Operator	161	$406.00	/day	$65,366.00			
Laborer	161	$341.60	/day	$54,997.60			
Environmental Tech	161	$200.00	/day	$32,200.00			
Equipment:							
Windrow Turner (6' x 19')	6	$45,000.00	/mo	$270,000.00			
Dozer	6	$3,500.00	/mo	$21,000.00			
Excavator	6	$4,000.00	/mo	$24,000.00			
Wheel Loader	6	$5,000.00	/mo	$30,000.00			
Tractor	184	$50.00	/hr	$9,200.00	In-use		
Tractor	1104	$30.00	/hr	$33,120.00	Stand-by		
Straw Blower	184	$40.00	/hr	$7,360.00	In-use		
Straw Blower	1104	$20.00	/hr	$22,080.00	Stand-by		
21000 gallon Frac Tank	6	$1,400.00	/mo	$8,400.00			
21000 gallon Frac Tank	6	$1,400.00	/mo	$8,400.00			
Trash/Pump Hose	1	$3,749.00	/ea	$3,749.00			
Office Trailer	6	$800.00	/mo	$4,800.00			
Porta Jon	6	$175.22	/mo	$1,051.32			
Generator	6	$170.35	/mo	$1,022.11			
P/U Truck	6	$1,800.00	/mo	$10,800.00			
Spectrophotometer	1	$3,012.00	/ls	$3,012.00			
Materials:							
Repl. Flails for Windrow Turner	17544	$9.50	/ea	$166,668.00			
Straw	14436	$11.25	/cy	$162,405.25			
Manure	581	$25.00	/cy	$14,516.11			
Water	1027	$9.40	/kgal	$9,653.80			
Level C PPE	966	$35.00	/day	$33,810.00			
Air Monitoring Screening Kits	1	$2,500.00	/ls	$2,500.00			
Moisture/Temp Probes	1	$700.00	/ea	$700.00			
Analytical:							
Pre-Compliance Sampling:							
EnSys Kit (TNT 20)	6	$572.00	/ea	$3,432.00			
- 19 samples per kit							
Total NACs	102	$145.00	/ea	$14,790.00			
Compliance Sampling:							
TCLP Semivolatiles	17	$175.00	/ea	$2,975.00			
Total NACs	17	$145.00	/ea	$2,465.00			
TCLP 2,4-DNT	17	$175.00	/ea	$2,975.00			
						Subtotal	**$1,422,091.00**

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Chemical Stabilization of Lead-Contaminated Soil

Includes:

1. Stabilization of lead contaminated soil utilizing Maectite chemical stabilization technology.

Assumptions and Calculations:

1. Volume of in-place lead contaminated soil to be stabilized (cy)= 1339 Soil haz Pb but not PCB
2. Swell factor for soil upon excavation = 1.3
3. Volume of unconsolidated lead-contaminated soil (cy) = 1741
4. Density of soil (ton/cy) = 1.1
5. Lead contaminated soil remains in-place for chemical stabilization.
6. An excavator will punch holes in the soil for installation of the Maectite chemical.
7. The Maectite shall be pumped into the holes.
8. The excavator will turn the soil and the chemical for ample mixture.
9. The production rate is 2 hours to mix 400 cy of soil.
10. Time required to stabilize soil (days) = 5
11. The lump sum price for the Maectite chemical and technician is $10,000 per Serverson Environmental.
12. Number of field crew = 1
13. Standard work week is 5 days per week at 8 hours per day. Thus, assuming 22 working days per 31 day month.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	40	$49.00	/hr	$1,960.00	
QA (Sampling) Coordinator	40	$36.00	/hr	$1,440.00	
H&S Coordinator	40	$49.00	/hr	$1,960.00	
Sampling Technician	40	$28.00	/hr	$1,120.00	
Equipment Operator	5	$406.00	/day	$2,030.00	
Equipment:					
Excavator	0.6	$4,000.00	/mo	$2,400.00	
Office Trailer	0.6	$800.00	/mo	$480.00	
Porta Jon	0.6	$175.22	/mo	$105.13	
Generator	0.6	$170.35	/mo	$102.21	
P/U Truck	0.6	$1,800.00	/mo	$1,080.00	
Materials:					
Maectite Chemical Stabilization	1	$10,000.00	/ls	$10,000.00	(Serverson tech incl)
Level D PPE	5	$10.00	/day	$50.00	
PID rental	0.6	$974.00	/mo.	$584.40	
CGI rental	0.6	$380.00	/mo.	$228.00	
Analytical:					
TCLP Extraction	1	$10.30	/ea	$10.00	
Lead	1	$24.00	/ea	$24.00	
SVOCs (8270C)	1	$175.00	/ea	$175.00	
NACs (8330)	1	$145.00	/ea	$145.00	
PCBs	1	$83.00	/ea	$83.00	
Shipping	1	$40.00	/ea	$40.00	
				Subtotal	**$24,017.00**

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

7.0 Off-Site Disposal

Includes:

1. Dispose of treated compost at a non-hazardous landfill.
2. Dispose of Maectite stabilized soil, and non-hazardous (not stabilized) soil at a non-hazardous waste landfill.
3. Analysis for off-site waste disposal.

Assumptions and Calculations:

1. Consolidated volume of D008 soil for haz disposal (cy) =	0	
2. Consolidated volume of D030 soil for haz disposal (cy) =	119	Soil haz 2,4-DNT+Pb+PCB
3. Consolidated volume of PCB soil for haz disposal (cy) =	0	Soil haz Pb+PCB
4. Total volume consolidated soil for haz disposal (cy) =	119	
5. Total volume unconsolidated soil for haz disposal (cy) =	155	
6. Weight of haz waste for disposal (tons) =	170	
7. Consolidated volume of untreated soil (cy) =	12807	
8. Unconsolidated volume untreated soil (cy) =	16649	
9. Weight of untreated soil (tons) =	18314	
10.Volume of compost, non-haz disposal (cy) =	15968	
11. Bulk density of compost (tons/cy) =	0.368	
12. Weight of treated compost, non-haz waste (ton) =	5876	
13. Consolidated volume of soil haz for 2,4-DNT and Pb (cy) =	1339	
14. Unconsolidated volume of stabilized soil not composted (cy) =	155	
15. Weight of stabilized soil not composted (tons) =	170	
16. Total volume non-haz waste for disposal (cy) =	32772	
17. Total weight of non-haz waste for disposal (tons) =	24361	
18. Non-haz waste transportation cost ($/hr) =	72	
19. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
20. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
21. Haz waste transportation cost ($/ton) =	35	
22. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
23. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
24. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
25. Haz waste regulatory fees ($/ton) =	10	
26. Number of crew =	3	
27. Load capacity of a 20 ton truck (tons) =	15	
28. Round trip travel time to non-haz waste landfill (hr) =	1	
29. Loads of non-haz waste or trips (hrs) =	1625	
30. Output of front-end loader (cy/day) =	550	
31. No. of wheel loaders =	2	
32. Number of field days =	30	
33. No. of truckloads of stormwater for disposal =	4	
34. Volume of stormwater per truckload (gal) =	4000	
35. Volume of stormwater requiring off-site disposal (gal) =	16000	
36. Stormwater shall be analyzed for TCLP semivolatiles prior to transport.		
37. At one sample per truckload, number of samples (ea) =	4	
38. Excavated soil is staged in 500 ton piles.		
39. One 10-point composite sample shall be collected from each 500-ton pile as part of compliance testing.		
40. Standard work week is 5 days per week at 8 hours per day.		

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

7.0 Off-Site Disposal (continued)					
Service/Materials	**Unit**	**Unit Cost**		**Subtotal**	
Labor:					
Site Superintendent	240	$49.00	/hr	$11,760.00	
QA Coordinator	240	$36.00	/hr	$8,640.00	
H&S Coordinator	240	$49.00	/hr	$11,760.00	
Equipment Operator	30	$406.00	/day	$12,180.00	
Equipment Operator	30	$406.00	/day	$12,180.00	
Oiler	30	$293.00	/day	$8,790.00	
Materials:					
Level D PPE	90	$10.00	/day	$900.00	
Equipment:					
Wheel Loader	1.4	$5,000.00	/mo	$7,000.00	
Wheel Loader	1.4	$5,000.00	/mo	$7,000.00	
Office Trailer	1.4	$800.00	/mo	$1,120.00	
Porta Jon	1.4	$175.22	/mo	$245.31	
Generator	1.4	$170.35	/mo	$238.49	
P/U Truck	1.4	$1,800.00	/mo	$2,520.00	
Disposal Costs:					
Transportation (Non-Haz Waste)	1625	$72.00	/hr	$117,000.00	truck & driver
Disposal Cost (Non-Haz waste)	24361	$24.50	/ton	$596,833.99	Erie County Landfill
Transportation (Haz Waste)	170	$35.00	/ton	$5,950.00	
Disposal Cost (D008 haz waste)	0	$85.00	/ton	$0.00	
Disposal Cost (D030 haz waste)	170	$160.00	/ton	$27,227.20	
Disposal Cost (PCB haz waste)	0	$85.00	/ton	$0.00	
Stormwater Disposal	16000	$0.25	/gal	$4,000.00	Enviro-Tank Clean
Analytical:					
Compliance Sampling:					
TCLP SVOC/NAC/metals	37	$400.00	/ea	$14,800.00	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$850,845.00**

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

8.0 Site Restoration

Includes:
1. Backfill excavated areas with clean backfill.
2. Re-seed site.
3. Perform road repair.

Assumptions and Calculations:

1. Volume of consolidated soil excavated (cy) =	17157
2. Compaction factor =	1.15
3. Volume of soil required for backfill (cy) =	19731
4. Cost of clean backfill soil delivered to site ($/cy) =	12
5. Output of front-end loader (cy/day) =	550
6. Field days required to backfill soil =	36
7. Number of field crew =	3

8. Upon completion of remedial action soil samples shall be taken within the laydown area to determine if any soil removal is required.
9. The laydown area shall be divided into 4 quarters and a 5-point composite collected (4 samples total).

10. Number of soil samples (ea) =	4

11. Allow 1 week for reseeding site and road repair.

12. Task duration (days) =	41

13. Standard work week is 5 days per week at 8 hours per day.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	328	$49.00	/hr	$16,072.00	
QA Coordinator	328	$36.00	/hr	$11,808.00	
H&S Coordinator	328	$49.00	/hr	$16,072.00	
Equipment Operator	36	$406.00	/day	$14,616.00	
Equipment Operator	36	$406.00	/day	$14,616.00	
Laborer	36	$341.60	/day	$12,297.60	
Reseeding	1.0	$5,000.00	/area	$5,000.00	
Road Repair	1.0	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	2	$3,500.00	/mo	$7,000.00	
Wheel Loader	2	$5,000.00	/mo	$10,000.00	
Office Trailer	2	$800.00	/mo	$1,600.00	
Porta Jon	2	$175.22	/mo	$350.44	
Generator	2	$170.35	/mo	$340.70	
P/U Truck	2	$1,800.00	/mo	$3,600.00	
Material:					
Backfill	19731	$12.00	/cy	$236,766.60	delivered to site
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Level D PPE	123	$10.00	/day	$1,230.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$530,517.00**

Table 4-5

Alternative 4 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

9.0 Overall Cost		
	Total Capital Cost	**$3,461,002.00**
	Contingency (30%)	**$1,038,301.00**
	PM Multiplier (7.5%)	**$259,575.00**
	Fee/Profit (10%)	**$346,100.00**
	Total Cost	**$5,105,000.00**

*This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative 5	**Site:**	TNT Area A
Excavation/Alkaline Hydrolysis/Windrow Composting/		Plum Brook Ordnance Works
Stabilization/On-Site & Off-Site Disposal	**Date:**	**12/8/2008**
Cost Estimate		

Scope:
1. Prepare work plans and closeout report, and complete procurement.
2. Mobilize/demobilize equipment and personnel.
3. Prepare site for remedial activity.
4. Excavate contaminated soil, perform confirmation sampling & characterize waste.
5. Alkaline hydrolysis and neutralization of soil that is hazardous due to 2,4-DNT TCLP.
6. Windrow composting of alkaline hydrolysis treated soil.
7. Maectite chemical stabilization of soil that is hazardous due to lead TCLP.
8. On site disposal of soil treated via alkaline hydrolysis and windrow composting.
9. Off-site disposal of non-hazardous waste.
10. Site restoration.

1.0 Treatability Study, Work Plans, Reports and Procurement

Includes:
1. Labor to generate work plans, including engineering specifications and Health and Safety Plan, along with the Final Report.
2. Procure equipment and materials.
3. Treatability study to test effectiveness w/PAHs and optimize neutralization approach.

Service	Unit	Unit Cost		Subtotal	
Work Plans and Final Report	1	$15,000.00	/ls	$15,000.00	
Procurement	1	$10,000.00	/ls	$10,000.00	
				Subtotal	**$25,000.00**

2.0 Mobilization/Demobilization of Equipment and Personnel

Includes:
1. Mobilization and demobilization of local equipment and personnel.
2. Set-up/tear down office trailer.

Assumptions:
1. Labor and equipment are available locally.
2. Pressure washer to be purchased for use during project.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor/Equipment:					
Mobe/Demobe	1	$5,000.00	/ls	$5,000.00	
Office Trailer (set up/tear down)	1	$500.00	/ls	$500.00	
Pressure Washer	1	$500.00	/ls	$500.00	
				Subtotal	**$6,000.00**

3.0 Site Preparation

Includes:
1. Existing site can be used and no additional site preparation costs are required.

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Excavation of Contaminated Soil

Includes:
1. Excavation of soil with contaminants exceeding RGOs.
2. Screen oversize material.
3. Collect confirmatory samples to verify extent of excavation.
4. Staging and characterizing waste stream.

Assumptions and Calculations:

1. Cubic yards of consolidated soil excavated =	17157
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	22304
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	24535
6. Capacity of screening plant (tons/hr) =	100
7. Excavator: hydraulic backhoe, 1 cy bucket.	
8. Excavator output (cy/day) =	600
9. Days to excavate soil =	45
10. Dump truck capacity (cy) =	12
11. Dump truck haul distance (mi.) =	0.5
12. Dump truck output (cy/day) =	250
13. No. of required dump trucks per day =	2
14. Soil sample collected for waste characterization / cy =	300
15. No. of soil samples collected for waste characterization =	74
16. Number of excavation crew =	2
17. Number of screening crew =	3
18. Lineal foot of excavation per confirmation sample =	20
19. Resampling factor for confirmation sampling =	1.1
20. No. of confirmatory samples from excavated area =	366
21. Excavation area (ft^2) =	51984
22. Cost multiplier for 1-week turnaround on analytical data =	1.25
23. Fraction of excavation work performed in Level C PPE =	0.10
24. Labor productivity factor for Level C work =	0.67
25. Days excavation crew in Level C =	5
26. Days screening crew in Level C =	4
27. Perimeter of excavation area (ft) =	4063
28. Excavation area (sf) =	51984
29. Volume of pit water requiring offsite disposal (gal) =	20000

30. Standard work week is 5 days per week at 8 hours per day. Thus, assuming 22 working days per 31 day month.

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	360	$49.00	/hr	$17,640.00
QA (Sampling) Coordinator	360	$36.00	/hr	$12,960.00
H&S Coordinator	360	$49.00	/hr	$17,640.00
Chemist (home office)	90	$51.00	/hr	$4,590.00
Equipment Operator	45	$406.00	/day	$18,270.00
Equipment Operator	35	$406.00	/day	$14,210.00
Equipment Operator	35	$406.00	/day	$14,210.00
Laborers	80	$341.60	/day	$27,328.00
Truck Drivers	90	$341.60	/day	$30,744.00

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0	**Excavation of Contaminated Soil (continued)**				
	Equipment:				
	Excavator	3	$4,000.00	/mo	$12,000.00
	100-ton/hr Screening Plant	7	$1,800.00	/wk	$12,600.00
	Radial Stacking Conveyor	7	$1,222.00	/wk	$8,554.00
	Dozer	2	$3,500.00	/mo	$6,125.00
	Dump Truck	3	$3,890.00	/mo	$11,670.00
	Dump Truck	3	$3,890.00	/mo	$11,670.00
	3000 gal. Water Truck	45	$402.00	/day	$18,090.00
	21,000 gal Frac Tank	14	$1,400.00	/mo	$19,600.00
	150 gpm Pump	3	$2,439.00	/ea.	$7,317.00
	300 gpm Pump	3	$3,749.00	/ea.	$11,247.00
	Office Trailer	3	$800.00	/mo	$2,400.00
	Porta Jon	3	$175.22	/mo	$525.66
	Generator	3	$170.35	/mo	$511.06
	P/U Truck	3	$1,800.00	/mo	$5,400.00
	Analytical:				
	TCLP Extraction	74	$12.88	/ea	$952.75
	SVOCs (8270C)	440	$300.00	/ea	$132,000.00
	NACs (8330)	440	$197.50	/ea	$86,900.00
	Lead	440	$30.00	/ea	$13,200.00
	PCBs	440	$103.75	/ea	$45,650.00
	NAC field analyses	366	$40.00	/ea	$14,640.00
	Lead field analyses	3	$4,200.00	/mo.	$12,600.00
	Shipping	117	$40.00	/ea	$4,693.33
	Materials & Services:				
	Level D PPE	173	$10.00	/day	$1,730.00
	Level C PPE	22	$35.00	/day	$770.00
	PID rental	3	$974.00	/mo.	$2,922.00
	CGI rental	3	$380.00	/mo.	$1,140.00
	Pit Water Disposal	20	$1.62	/kgal	$32.40
				Subtotal	**$602,532.00**

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Alkaline Hydrolysis with Neutralization

Includes:

1. Treat the 2,4-DNT contaminated soil with caustic soda pellets and 30% ferric chloride solution.
2. Neutralize alkaline hydrolysis treated soil with ferrous sulfate.
3. Temporary storage for the caustic soda pellets, 30% ferric chloride, and ferrous sulfate.

Assumptions and Calculations:

1. Volume of consolidated 2,4 DNT soil to be treated (cy) =		3803	
2. Swell factor for soil upon excavation =		1.3	
3. Cubic yards of unconsolidated soil =		4944	
4. Soil shall be treated via alkaline hydrolysis using caustic acid in 300 cy batches within the treatment area.			
5. Each 300 cy area =	52 ft Wide	52 ft Long	
6. Batch size (cy) =		300	
7. Soil to be spread out to a depth of (ft) =		3	
8. Treatment chemical requirements based on treatability study conducted by Shaw E&I Technology Dev. Lab			
9. Caustic soda, NaOH pellets =		61	lb/cy soil
10. Water, used to saturate soil with water =		37	gal/cy soil
11. Ferric chloride 30% solution =		1	gal/cy soil
12. NaOH mol wt =		40	lb/lb mol
13. Ferrous sulfate needed to neutralize NaOH =		108	lb/cy soil
14. Number of days for completed treatment with neutralization =		10	
15. Number of batches =		17	
16. Number of batches during one treatment cycle =		5	
17. Number of treatment cycles =		4	
18. Standard work week is 5 days per week at 8 hours per day. Thus, assuming 22 working days per 31 day month.			
19. Number of field days =		40	
20. Number of field crew =		8	
21. Mass of caustic soda (lb) =		301584	
22. Volume of ferric chloride, 30% solution (gal) =		4944	
23. Density of 30% ferric chloride solution (lb/gal) =		10.77	
24. Volume of water (gal) =		182928	

25. Confirmation sampling for alkaline hydrolysis prior to neutralization shall consist of nitroaromatics, nitrate and nitrite, and pH, one sequence per batch.
26. Upon neutralization with the citric acid confirmation sampling shall be performed for nitrate and nitrite, and pH, one sequence per batch.
27. Temporary storage is required for the caustic soda pellets, 30% ferric chloride, and ferrous sulfate preventing exposure to inclement weather and release into the environment. The duration for the alkaline hydrolysis is 20 days. Therefore assume equipment rental for 1.5 months.
28. The caustic soda pellets come in 2000 pound super sacks at approximately 4-feet by 4-feet by 3-feet high.

29. Number of caustic soda super sacks (ea) =	151	
30. Required storage capacity for caustic soda pellets (cf) =	7248	

31. The 30% ferric chloride solution comes in 330 gallon totes at approximately 46.5-inches by 46.5-inches by 48-inches high.

32. Number of 30% ferric chloride solution totes (ea) =	15	
33. Required storage capacity for 30% ferric acid solution (cf) =	901	

34. The ferrous sulfate comes in 2,000 pound super sacks at 4-feet by 4-feet by 3-feet high or a 48 cubic feet pallet.

35. Number of ferrous sulfate super sacks or pallets (ea) =	268	
36. Required storage capacity for ferrous sulfate (cf) =	12864	

37. Temporary storage shall be provided utilizing a 48-foot swing open-door land-sea cargo trailer. The trailer is 45.42-feet long by 8.25 -feet wide by 9-feet high. 40 super sacks per trailer. The monthly rental is $100/mo.

38. Available capacity in the Land-Sea Cargo Trailer (cf) =	1920	
39. Number of Land-Sea Cargo Trailers for caustic soda pellets (ea)		8
40. Number of Land-Sea Cargo Trailers for 30% ferric chloride solution (ea) =		2
41. Number of Land-Sea Cargo Trailers for ferrous sulfate (ea) =		7

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Alkaline Hydrolysis with Neutralization (continued)					
Service/Materials	**Unit**	**Unit Cost**		**Subtotal**	
Labor:					
Site Superintendent	320	$49.00	/hr	$15,680.00	
QA (Sampling) Coordinator	320	$36.00	/hr	$11,520.00	
H&S Coordinator	320	$49.00	/hr	$15,680.00	
Sampling Technician	320	$28.00	/hr	$8,960.00	
Equipment Operator	40	$406.00	/day	$16,240.00	
Equipment Operator	40	$406.00	/day	$16,240.00	
Equipment Operator	40	$406.00	/day	$16,240.00	
Equipment Operator	40	$406.00	/day	$16,240.00	
Equipment Operator	40	$406.00	/day	$16,240.00	
Equipment Operator	40	$406.00	/day	$16,240.00	
Laborer	40	$341.60	/day	$13,664.00	
Laborer	40	$341.60	/day	$13,664.00	
Equipment:					
Dozer	2	$3,500.00	/mo	$7,000.00	
Excavator	2	$4,000.00	/mo	$8,000.00	
Excavator	2	$4,000.00	/mo	$8,000.00	
Front End Loader	2	$5,000.00	/mo	$10,000.00	
Fork Lift	2	$6,480.00	/mo	$12,960.00	
Fork Lift	2	$6,480.00	/mo	$12,960.00	
4000 gal. Water Truck	2	$402.00	/day	$804.00	
21,000 gal Frac Tank	4	$1,400.00	/mo	$5,600.00	
Air Monitoring	2	$750.00	/ls	$1,500.00	
Office Trailer	2	$800.00	/mo	$1,600.00	
Porta Jon	2	$175.22	/mo	$350.44	
Generator	2	$170.35	/mo	$340.70	
P/U Truck	2	$1,800.00	/mo	$3,600.00	
Materials:					
Caustic Soda	301584	$0.45	/lb	$135,712.80	Brenntag - Pgh
Ferric Chloride 30% Solution	53247	$0.15	/lb	$7,987.05	Brenntag - Pgh
Water	183	$9.40	/1000 gal	$1,720.20	
Ferrous Sulfate	535930	$0.11	/lb	$58,416.37	Crown Technology
Level C PPE	320	$35.00	/day	$11,200.00	
PID rental	2.0	$974.00	/mo.	$1,948.00	
CGI rental	2.0	$380.00	/mo.	$760.00	
Chem Storage - NaOH pellets	16	$100.00	/mo.	$1,600.00	
Chem Storage - 30% $FeCl_3$	4	$100.00	/mo.	$400.00	
Chem. Storage - $FeSO_4$*7H_2O	14	$100.00	/mo.	$1,400.00	
Analytical:					
Pre-Compliance Sampling:					
pH meter	1	$1,800.00	/ea	$1,800.00	
Compliance Sampling for Alkaline Hydrolysis:					
NACs (8330)	17	$145.00	/ea	$2,465.00	
TCLP 2,4-DNT	17	$173.00	/ea	$2,941.00	
E300 - Nitrite and Nitrate	17	$15.00	/ea	$255.00	
Compliance Sampling Following Neutralization with Ferrous Sulfate:					
E300 - Nitrite and Nitrate	17	$15.00	/ea	$255.00	
				Subtotal	**$478,184.00**

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Windrow Composting of Contaminated of Soil

Includes:
1. Rental of composting equipment.
2. Procurement & stockpiling of composting amendments.
3. Mix and compost soil and amendments.
4. Pre-compliance testing: after compost formation & at end of treatment.
5. Pre-compliance testing using definitive field analysis for NAC.

Assumptions:

1. Laydown area is 260' feet wide x 800 feet long.	
2. 75% of laydown area is available for windrows ad 25% is available for stockpiling amendments.	
3. Compost recipe is 25% soil, 2.9% agricultural amendment (manure) and 72.1% bulking amendment (straw).	
4. Widrows are spaced 5 feet apart from one another.	
5. There is a 35-foot space at each end of the windrow allotting for movement of the windrow turner.	
6. Duration per batch (wk) =	2
7. The windrows will be staggered by 1 week.	
8. Fraction of alkaline hydrolysis treated soil to be composted =	20%
9. Volume of alkaline hydrolysis treated soil to be composted (cy) =	761
10. Fraction of remaining soil treated via alkaline hydrolysis only =	80%
11. Volume of remaining alkaline hydrolysis treated soil (cy) =	3042
12. Swell factor for soil upon excavation =	1.3
13. Volume of unconsolidated soil to be treated (cy) =	989
14. Compost treatment duration (weeks) =	6
15. Each windrow is 6 feet high x 16 feet wide x 530 feet long, trapezoidal configuration.	
16. Capacity of windrow turner (tons/hr) =	3,200
17. Operating life of flails (hrs) =	25
18. Number of flails on windrow turner =	172
19. Volume of compost per windrow (cy) =	1,178
20. Per windrow the soil volume is, at 25% (cy) =	294
21. Per windrow the manure volume is, at 2.9% (cy) =	34
22. Per windrow the straw volume is, at 72.1% (cy) =	849
23 . Number of required windrows (ea) =	3.4
24. Volume of manure (cy) =	115
25. Volume of straw (cy) =	2852
26. Compost additive volume correction factor =	0.8
27. Total volume of compost prior to treatment (cy) =	3,164
28. Bulk density of compost (tons/cy) =	0.368
29. Number of field crew =	6
30. Tractor and straw blower are in-use 1 day/week and on stand-by the rest of the week.	
31. Pre-compliance testing shall weekly per windrow and consist of:	
- EnSys TNT 20, one per batch. Number of samples =	8
- EnSys TNT 20, no. of samples per kit =	19
- Total NAC, one per batch. Number of samples =	8
32. Compliance testing shall be performed per windrow and upon compost treatment. Sampling shall consist of:	
- Total Semivolatiles. Number of samples =	4
- Total NACs. Number of samples =	4
-TCLP 2,4-DNT. Number of samples =	4
33. Standard work week is 7 days per week at 8 hours per day. Thus, assuming 30 working days per month.	

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Windrow Composting of Contaminated of Soil (continued)

Service/Materials	Unit	Unit Cost		Subtotal		
Labor:						
Site Superintendent	336	$49.00	/hr	$16,464.00		
QA (Sampling) Coordinator	336	$36.00	/hr	$12,096.00		
H&S Coordinator	336	$49.00	/hr	$16,464.00		
Windrow Turner Operator	42	$567.20	/day	$23,822.40		
Equipment Operator	42	$406.00	/day	$17,052.00		
Equipment Operator	42	$406.00	/day	$17,052.00		
Equipment Operator	42	$406.00	/day	$17,052.00		
Laborer	42	$341.60	/day	$14,347.20		
Environmental Tech	42	$200.00	/day	$8,400.00		
Equipment:						
Windrow Turner (6' x 19')	2	$45,000.00	/mo	$90,000.00		
Dozer	2	$3,500.00	/mo	$7,000.00		
Excavator	2	$4,000.00	/mo	$8,000.00		
Wheel Loader	2	$5,000.00	/mo	$10,000.00		
Tractor	48	$50.00	/hr	$2,400.00	In-use	
Tractor	288	$30.00	/hr	$8,640.00	Stand-by	
Straw Blower	48	$40.00	/hr	$1,920.00	In-use	
Straw Blower	288	$20.00	/hr	$5,760.00	Stand-by	
21000 gallon Frac Tank	2	$1,400.00	/mo	$2,800.00		
21000 gallon Frac Tank	2	$1,400.00	/mo	$2,800.00		
Trash/Pump Hose	2	$3,749.00	/ea	$7,498.00		
Office Trailer	2	$800.00	/mo	$1,600.00		
Porta Jon	2	$175.22	/mo	$350.44		
Generator	2	$170.35	/mo	$340.70		
P/U Truck	2	$1,800.00	/mo	$3,600.00		
Spectrophotometer	2	$3,012.00	/ls	$6,024.00		
Materials:						
Repl. Flails for Windrow Turner	1032	$9.50	/ea	$9,804.00		
Straw	2852	$11.25	/cy	$32,080.97		
Manure	115	$25.00	/cy	$2,867.46		
Water	1027	$9.40	/kgal	$9,653.80		
Level C PPE	252	$35.00	/day	$8,820.00		
Air Monitoring Screening Kits	1	$2,500.00	/ls	$2,500.00		
Moisture/Temp Probes	1	$700.00	/ea	$700.00		
Analytical:						
Pre-Compliance Sampling:						
EnSys Kit (TNT 20)	1	$572.00	/ea	$572.00		
- 19 samples per kit						
Total NACs	8	$145.00	/ea	$1,160.00		
Compliance Sampling:						
TCLP Semivolatiles	4	$175.00	/ea	$700.00		
Total NACs	4	$145.00	/ea	$580.00		
TCLP 2,4-DNT	4	$175.00	/ea	$700.00		
				Subtotal		**$371,621.00**

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

7.0 Chemical Stabilization of Lead-Contaminated Soil

Includes:

1. Stabilization of lead contaminated soil utilizing Maectite chemical stabilization technology.

Assumptions and Calculations:

1. Volume of in-place lead contaminated soil to be stabilized (cy)= 1339
2. Swell factor for soil upon excavation = 1.3
3. Volume of unconsolidated lead-contaminated soil (cy) = 1741
4. Density of soil (ton/cy) = 1.1
5. Lead contaminated soil remains in-place for chemical stabilization.
6. An excavator will make depressions in the soil for Maectite chemical application.
7. The excavator will turn the soil and the chemical for ample mixture.
8. Time required to stabilize soil (days) = 5
9. The lump sum price for the Maectite chemical and technician is $10,000 per Serverson Environmental.
10. Number of field crew = 1
11. Standard work week is 5 days per week at 8 hours per day. Thus, assuming 22 working days per 31 day month.
12. The 590 cy of in-place lead soil included 582 cy of in-place soil also containing 2-4, DNT.
13. Volume of in-place soil to receive treatment via alkaline hydrolysis and Maectite chemical stabilization (cy) = 582
14. All soil treated via Maectite chemical stabilization shall be disposed offsite.
15. Volume of soil to receive Maectite chemical stabilization only (cy) = 757

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	40	$49.00	/hr	$1,960.00	
QA (Sampling) Coordinator	40	$36.00	/hr	$1,440.00	
H&S Coordinator	40	$49.00	/hr	$1,960.00	
Sampling Technician	40	$28.00	/hr	$1,120.00	
Equipment Operator	5	$406.00	/day	$2,030.00	
Equipment:					
Excavator	0.6	$4,000.00	/mo	$2,400.00	
Office Trailer	0.6	$800.00	/mo	$480.00	
Porta Jon	0.6	$175.22	/mo	$105.13	
Generator	0.6	$170.35	/mo	$102.21	
P/U Truck	0.6	$1,800.00	/mo	$1,080.00	
Materials:					
Maectite Chemical Stabilization	1	$10,000.00	/ls	$10,000.00	(Serverson tech incl)
Level D PPE	5	$10.00	/day	$50.00	
PID rental	0.6	$974.00	/mo.	$584.40	
CGI rental	0.6	$380.00	/mo.	$228.00	
Analytical:					
TCLP Extraction	1	$10.30	/ea	$10.00	
Lead	1	$24.00	/ea	$24.00	
SVOCs (8270C)	1	$175.00	/ea	$175.00	
NACs (8330)	1	$145.00	/ea	$145.00	
PCBs	1	$83.00	/ea	$83.00	
Shipping	1	$40.00	/ea	$40.00	
				Subtotal	**$24,017.00**

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

8.0 On-Site Disposal

Includes:

1. Load treated compost, truck to site, spread compost with dozer
2. Load alkaline hydrolysis treated soil and stockpile for use as backfill material. The material shall be used as backfill and is addressed in Section 10.0.
3. Confirmation testing under contaminated soil stockpiles.

Assumptions and Calculations:

Composted material (treated via alkalyne hydrolysis and windrow composting):

1. Total volume of compost before treatment (cy) =	3,164	
2. Bulk density of compost (tons/cy) =	0.368	
3. Weight of treated compost, non-haz waste (ton) =	1164	
4. Loader output (cy/day) =	1735	
5. Days to load treated compost =	3	
6. Dump truck capacity (cy) =	12	
7. Dump truck haul distance (mi.) =	0.5	
8. Dump truck output (cy/day) =	300	
9. No. of dump trucks per day =	6	
10. Dozer (D-6H) capacity (cy/day) =	595	
11. Number of dozers =	2	
12. Days to spread treated compost =	3	

13. The loading and hauling activities shall be performed consecutively. The spreading activity shall commence 2 days after loading/hauling commences.

14. The duration to load, haul, and spread composted material (days) =	5	
Remaining treated soil via alkaline hydrolysis only:		
15. Volume of alkaline hydrolysis treated soil (cy) =	3,042	
16. Less the volume of lead soil treated via alkaline hydrolysis and Maectite chemical stabilization (cy) =	582	(Shall be disposed off-site.)
17. Volume of alkalyne hydrolysis treated soil for on-site disposal (cy) =	2,460	
18. Swell factor for soil upon excavation =	1.3	
19. Volume of unconsolidated soil used as backfill material (cy) =	3199	
20. Loader output (cy/day) =	1735	
21. Days to load alkaline hydrolysis treated soil =	3	
22. Dump truck capacity (cy) =	12	
23. Dump truck haul distance (mi.) =	0.5	
24. Dump truck output (cy/day) =	300	
25. No. of dump trucks per day =	6	

26. The treated soil via alkaline hydrolysis only shall be stockpiled prior to use as backfill material as part of Site Restoration.

27. The loading and hauling activities shall be performed consecutively.

28. The duration to load, haul, and spread composted material (days) = 3

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	64	$49.00	/hr	$3,136.00
QA Coordinator	64	$36.00	/hr	$2,304.00
Equipment Operator	6	$406.00	/day	$2,436.00
Equipment Operator	3	$406.00	/day	$1,218.00
Equipment Operator	3	$406.00	/day	$1,218.00
Laborer/Oiler	6	$293.00	/day	$1,758.00
Laborer/Oiler	3	$293.00	/day	$879.00
Laborer/Oiler	3	$293.00	/day	$879.00
Truck Drivers	36	$341.60	/day	$12,297.60

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

8.0	**On-Site Disposal (Continued)**						
	Equipment:						
		Wheel Loader	1	$5,000.00	/mo	$5,000.00	
		Dump Truck (6 ea)	2	$3,890.00	/mo	$6,224.00	
		Dozer (2 ea)	1	$3,500.00	/mo	$3,500.00	
		Office Trailer	1	$800.00	/mo	$880.00	
		Porta Jon	1	$175.22	/mo	$192.74	
		Generator	1	$170.35	/mo	$187.39	
		P/U Truck	1	$1,800.00	/mo	$1,980.00	
	Material:						
		PID rental	1	$974.00	/mo.	$1,071.40	
		CGI rental	1	$380.00	/mo.	$418.00	
		Level D PPE	60	$10.00	/day	$600.00	
						Subtotal	**$46,179.00**

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

9.0 Off-Site Disposal

Includes:
1. Dispose non-treated soil at a non-hazardous facility.

Assumptions and Calculations:

1. Consolidated volume of D008 soil for haz disposal (cy) =	0	
2. Consolidated volume of D030 soil for haz disposal (cy) =	119	Soil haz 2,4-DNT+Pb+PCB
3. Consolidated volume of PCB soil for haz disposal (cy) =	0	Soil haz Pb+PCB
4. Total volume of consolidated hazardous soil (cy) =	119	
5. Total volume of unconsolidated hazardous soil (cy) =	155	
6. Consolidated (in-place) volume of treated soil (cy) =	4231	
7. Unconsolidated volume of treated soil (cy) =	5500	
8. Weight of treated soil (tons) =	6050	
10. Consolidated volume of untreated soil (cy) =	12807	
11. Unconsol vol untreated soil for non-hazardous disposal (cy) =	16649	
12. Weight of untreated soil (ton) =	18314	
13. Consolidated volume of lead -contaminated soil treated via Maectite chemical stabilization (cy) =	1339	
14. Swell factor for soil upon excavation =	1.3	
15. Volume of unconsolidated lead-contaminated soil via Maectite chemical stabilization for non-hazardous disposal (cy) =	1741	
16. Total volume of non-haz waste for disposal (cy) =	18390	
17. Weight of lead-contaminated soil via Maectite chemical stabilization (ton) =	1915	
18. Total weight of non-haz waste for disposal (tons) =	20229	
19. Non-haz waste transportation cost ($/hr) =	72	
20. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
21. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
22. Haz waste transportation cost ($/ton) =	35	
23. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
24. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
25. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
26. Haz waste regulatory fees ($/ton) =	10	
27. No. of field crew =	4	
28. Load capacity of a 20 ton truck (tons) =	15	
29. Round trip travel time to non-haz waste landfill (hr) =	1	
30. Loads of non-haz waste or trips (hrs)=	1349	
31. Output of wheel loader (cy/day) =	550	
32. No. of wheel loaders on site =	2	
33. No. of field days =	17	
34. No. of truckloads of stormwater for off-site disposal =	4	
35. Volume of water truck (gal) =	4000	
36. Volume of stormwater requiring off-site disposal (gal) =	16000	

37. Stormwater shall be analyzed for TCLP semivolatiles prior to transport.

38. At one sample per truckload, number of samples (ea) =	4

39. Excavated soil is staged in 500 ton piles.
40. One 10-point composite sample shall be collected from each 500-ton pile as part of compliance testing.
41. Standard work week is 5 days per week at 8 hours per day.

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

9.0 Off-Site Disposal (continued)

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	136	$49.00	/hr	$6,664.00	
QA Coordinator	136	$36.00	/hr	$4,896.00	
H&S Coordinator	136	$49.00	/hr	$6,664.00	
Equipment Operator	17	$406.00	/day	$6,902.00	
Equipment Operator	17	$406.00	/day	$6,902.00	
Laborer/Oiler	17	$293.00	/day	$4,981.00	
Laborer/Oiler	17	$293.00	/day	$4,981.00	
Materials:					
Level D PPE	68	$10.00	/day	$680.00	
Equipment:					
Wheel Loader	1.0	$5,000.00	/mo	$5,000.00	
Wheel Loader	1.0	$5,000.00	/mo	$5,000.00	
Office Trailer	1.0	$800.00	/mo	$800.00	
Porta Jon	1.0	$175.22	/mo	$175.22	
Generator	1.0	$170.35	/mo	$170.35	
P/U Truck	1.0	$1,800.00	/mo	$1,800.00	
Disposal Costs:					
Transportation (Non-Haz Waste)	1349	$72.00	/hr	$97,128.00	truck & driver
Disposal Cost (Non-Haz waste)	20229	$24.50	/ton	$495,610.50	
Transportation (Haz Waste)	170	$35.00	/ton	$5,955.95	
Disposal Cost (D008 haz waste)	0	$85.00	/ton	$0.00	
Disposal Cost (D030 haz waste)	170	$160.00	/ton	$27,227.20	
Disposal Cost (PCB haz waste)	0	$85.00	/ton	$0.00	
Stormwater Disposal	16000	$0.25	/gal	$4,000.00	Enviro-Tank Clean
Analytical:					
Compliance Sampling:					
TCLP SVOC/NAC/metals	18	$400.00	/ea	$7,333.73	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$693,571.00**

10.0 Site Restoration

Includes:
1. Backfill excavated areas with alkaline hydrolysis treated soil and clean backfill.
2. Re-seed site.
3. Perform road repair.

Assumptions and Calculations:

1. Required volume of consolidated soil for excavated area (cy) =	17157	
2. Compaction factor =	1.15	
3. Volume of soil required for backfill (cy) =	19731	
4. Volume of alkaline hydrolysis treated soil (cy) =	3199	(less the lead contaminated soil)
5. Volume of required clean backfill (cy) =	16532	
6. Cost of clean backfill soil delivered to site ($/cy) =	12	
7. Output of front-end loader (cy/day) =	550	
8. Field days required to backfill soil =	31	
9. No. of field crew =	3	

10. Upon completion of remedial action, soil samples shall be taken within the laydown area to determine if any soil removal is required.
11. The laydown area shall be divided into 4 quarters and a 5-point composite collected (4 samples total).
12. No. of soil samples (ea) = 4
13. Allow 1 week for reseeding site and road repair.
14. Task duration (days) = 36
15. Standard work week is 5 days per week at 8 hours per day. Thus, assuming 22 working days per month.

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	288	$49.00	/hr	$14,112.00	
QA Coordinator	288	$36.00	/hr	$10,368.00	
H&S Coordinator	288	$49.00	/hr	$14,112.00	
Equipment Operator	31	$406.00	/day	$12,586.00	
Equipment Operator	31	$406.00	/day	$12,586.00	
Laborer	31	$341.60	/day	$10,589.60	
Reseeding	1	$5,000.00	/area	$5,000.00	
Road Repair	1	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	2	$3,500.00	/mo	$7,000.00	
Wheel Loader	2	$5,000.00	/mo	$10,000.00	
Office Trailer	2	$800.00	/mo	$1,600.00	
Porta Jon	2	$175.22	/mo	$350.44	
Generator	2	$170.35	/mo	$340.70	
P/U Truck	2	$1,800.00	/mo	$3,600.00	
Material:					
Backfill	16532	$12.00	/cy	$198,384.36	delivered to site
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Level D PPE	108	$10.00	/day	$1,080.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$480,857.00**

Table 4-7

Alternative 5 Cost Estimate
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

11.0 Overall Cost		
	Total Capital Cost	**$2,727,961.00**
	Contingency (30%)	**$818,388.00**
	PM Multiplier (7.5%)	**$204,597.00**
	Fee/Profit (10%)	**$272,796.00**
	Total Cost	**$4,024,000.00**

*This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Overall Protectiveness					
Human Health Protection	No reduction in risk.	Reduces the concentration of COCs to levels below RGs.	Reduces the concentration of COCs to levels below RGs.	Reduces the concentration of COC to levels below RGs.	Reduces the concentration of COC to levels below RGs.
Environmental Protection	No reduction in risk.	Significantly reduces the hazard quotients calculated for ecological receptors, and lowers the likelihood of contaminant spread to other media.	Significantly reduces the hazard quotients calculated for ecological receptors, and lowers the likelihood of contaminant spread to other media.	Significantly reduces the hazard quotients calculated for ecological receptors, and lowers the likelihood of contaminant spread to other media.	Significantly reduces the hazard quotients calculated for ecological receptors, and lowers the likelihood of contaminant spread to other media.
Compliance with ARARs					
Chemical-Specific ARARs	No chemical-specific ARARs.	No chemical-specific ARARs.	No chemical-specific ARARs.	No chemical-specific ARARs.	No chemical-specific ARARs.
Location-Specific ARARs	No location-specific ARARs.	Complies with all location-specific ARARs.	Complies with all location-specific ARARs.	Complies with all location-specific ARARs.	Complies with all location-specific ARARs.
Action-Specific ARARs	No action-specific ARARs.	Complies with all action-specific ARARs.	Complies with all action-specific ARARs.	Complies with all action-specific ARARs.	Complies with all action-specific ARARs.
Other Criteria and Guidance	Permits exposures to soil exceeding the USEPA 400 mg/kg screening level for lead in soil.	Prevents exposures to soil exceeding the USEPA 400 mg/kg screening level for lead in soil.	Prevents exposures to soil exceeding the USEPA 400 mg/kg screening level for lead in soil.	Prevents exposures to soil exceeding the USEPA 400 mg/kg screening level for lead in soil.	Prevents exposures to soil exceeding the USEPA 400 mg/kg screening level for lead in soil.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Long-Term Effectiveness and Permanence					
Magnitude of Residual Risk	Existing risk will remain.	Residual risk will be within the risk management range.	Residual risk will be within the risk management range.	Residual risk will be within the risk management range.	Residual risk will be within the risk management range.
Adequacy and Reliability of Controls	No controls over remaining contamination. No reliability.	No long-term controls required at site.	No long-term controls required at site.	No long-term controls required at site.	No long-term controls required at site.
Reduction of Toxicity, Mobility, or Volume through Treatment					
Treatment Process Used	None	Biological treatment of nitroaromatic compounds and PAHs using windrow composting.	No on-site treatment.	Biological treatment of nitroaromatic compounds and PAHs using windrow composting. Ex-situ chemical stabilization of lead.	Chemical and biological treatment of nitroaromatic compounds and PAHs using alkaline hydrolysis and windrow composting. Ex-situ chemical stabilization of lead.
Amount Destroyed or Treated	None	20% of contaminated soil treated on-site.	No on-site treatment.	23% of contaminated soil treated on-site.	23% of contaminated soil treated on-site.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Irreversible Treatment	None.	Research has demonstrated that a high percentage (>80%) of TNT-carbon is irreversibly bound to the soil through covalent binding with humic substances.	No on-site treatment.	Research has demonstrated that a high percentage (>80%) of TNT-carbon is irreversibly bound to the soil through covalent binding with humic substances. Stabilization may not be an irreversible process, but placement of stabilized waste in an engineered disposal cell minimizes the possibility that conditions conducive to leaching will be created.	Alkaline hydrolysis irreversibly transforms NACs in soil to less toxic end products. Research has demonstrated that a high percentage (>80%) of TNT-carbon is irreversibly bound to the soil through covalent binding with humic substances. Research has demonstrated that a high percentage (>80%) of TNT-carbon is irreversibly bound to the soil through covalent binding with humic substances. Stabilization may not be an irreversible process, but placement of stabilized waste in an engineered disposal cell minimizes the possibility that conditions conducive to leaching will be created.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Type and Quantity of Residuals Remaining after Treatment (all volumes are based on in-place, consolidated soil)	Contaminated soil remains.	15,699 cy of treated and untreated soil for offsite disposal as a nonhazardous waste at a solid waste landfill. 1339 cy lead contaminated soil for off-site treatment & disposal at a Subtitle C TSDF. 119 cy PCB remediation waste for offsite treatment and/or disposal at TSCA approved TSDF.	12,380 cy of untreated soil for offsite disposal as a nonhazardous waste at a solid waste landfill. 4,658 cy of 2,4-DNT and lead contaminated soil for offsite treatment and disposal at a hazardous waste TSDF. 119 cy PCB remediation waste for offsite treatment and/or disposal at TSCA approved TSDF.	17,038 cy of treated and untreated soil for offsite disposal as a non-hazardous waste at a solid waste landfill. 119 cy PCB remediation waste for offsite treatment & disposal at TSCA approved TSDF.	3,319 cy of treated soil placed back on site. 13,719 cy untreated soil and lead contaminated soil for off-site disposal at a nonhazardous waste landfill. 119 cy PCB remediation waste for offsite treatment and/or disposal at TSCA approved TSDF.
Short-Term Effectiveness					
Community Protection	May present future risk to community.	Normal safeguards would be required during transportation of waste materials offsite.	Normal safeguards would be required during transportation of waste materials offsite.	Normal safeguards would be required during transportation of waste materials offsite.	Normal safeguards would be required during transportation of waste materials offsite.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Worker Protection	No risk to workers	Safeguards would be required to protect workers from chemical exposures during windrow turning operations. Dust released during excavation, screening, amendment mixing, and windrow turning may require controls.	Dust released during excavation and screening may require controls.	Safeguards would be required to protect workers from chemical exposures during windrow turning operations. Dust released during excavation, screening, amendment mixing, windrow turning, and stabilization may require controls.	Chemicals used in the treatment process are very corrosive. Material handling processes must be carefully designed to protect workers from chemical exposures. Safeguards would be required to protect workers from chemical exposures during windrow turning operations. Dust released during excavation, screening, amendment mixing, windrow turning, and stabilization may require controls.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Environmental Impacts	Continued impact from existing conditions.	Design of staging piles (contaminated soil and amendments) would require safeguards to prevent migration of contaminants. Treatment area would be bermed and a contact water retention system provided to control stormwater run-on and run-off.	Design of staging piles would require safeguards to prevent migration of contaminants.	Design of staging piles would require safeguards to prevent migration of contaminants. Treatment area would be bermed and a contact water retention system provided to control stormwater run-on and run-off.	Design of staging piles would require safeguards to prevent migration of contaminants. Treatment area would be bermed and a contact water retention system provided to control stormwater run-on and run-off. Hazardous chemicals would be managed to segregate incompatible chemicals and prevent uncontrolled releases to the environment.
Time Until Action is Complete	Not applicable	18 to 24 months	12 to 18 months	19 to 25 months	21 to 27 months

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Implementability					
Ability to Construct and Operate	No construction or operation.	Technology well developed and implemented on a full-scale basis at numerous sites. Composting previously implemented at TNTB.	No significant issues.	Technologies well developed and implemented on a full-scale basis at numerous sites. Composting previously implemented at TNTB.	Alkaline hydrolysis using caustic soda to treat NACs in soil is a relatively new process, but has been field tested at one site. Composting is a contingency component of remedial alternative that will be used to treat soil that does not meet RGs or LDR criteria after alkaline hydrolysis. Composting is a well developed technology implemented on a full-scale basis at numerous sites. Composting previously implemented at TNTB.
Ease of Doing More Action if Needed	May require ROD amendment if future problems arise.	Does not preclude additional remedial action for soil.	Does not preclude additional remedial action for soil.	Does not preclude additional remedial action for soil.	Does not preclude additional remedial action for soil.

Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Ability to Monitor Effectiveness	No monitoring required.	Effectiveness of excavation is evaluated by confirmatory soil sampling and analysis. Effectiveness of composting is evaluated by post-treatment sampling and analysis of compost	Effectiveness of excavation is evaluated by confirmatory soil sampling and analysis.	Effectiveness of excavation is evaluated by confirmatory soil sampling and analysis. Effectiveness of stabilization process evaluated through leaching tests. Effectiveness of composting is evaluated by post-treatment sampling and analysis of treated soil.	Effectiveness of excavation is evaluated by confirmatory soil sampling and analysis. Effectiveness of stabilization process evaluated through leaching tests. Effectiveness of alkaline hydrolysis and composting is evaluated by post-treatment sampling and analysis of treated soil
Ability to Obtain Approvals and Coordinate with Other Agencies	None required	OEPA approval of disposal facility would be required.	OEPA approval of disposal facility would be required.	OEPA approval of disposal facility would be required.	OEPA approval of disposal facility would be required.
Availability of Equipment, Specialists, and Materials	None required	Equipment, technical specialists, and materials available locally.	Equipment, technical specialists, and materials available locally.	Equipment, technical specialists, and materials readily available.	Equipment, technical specialists, and materials readily available.
Availability of Technologies	None required	Available	Available	Available	Available
Cost					
Capital Cost	None	$5.2 million	$4.7 million	$5.1 million	$4.0 million
Annual O&M Cost	None	None	None	None	None
Present Worth Cost	None	$5.2 million	$4.7 million	$5.1 million	$4.0 million
State Acceptance	Not acceptable	To be determined	To be determined	To be determined	To be determined

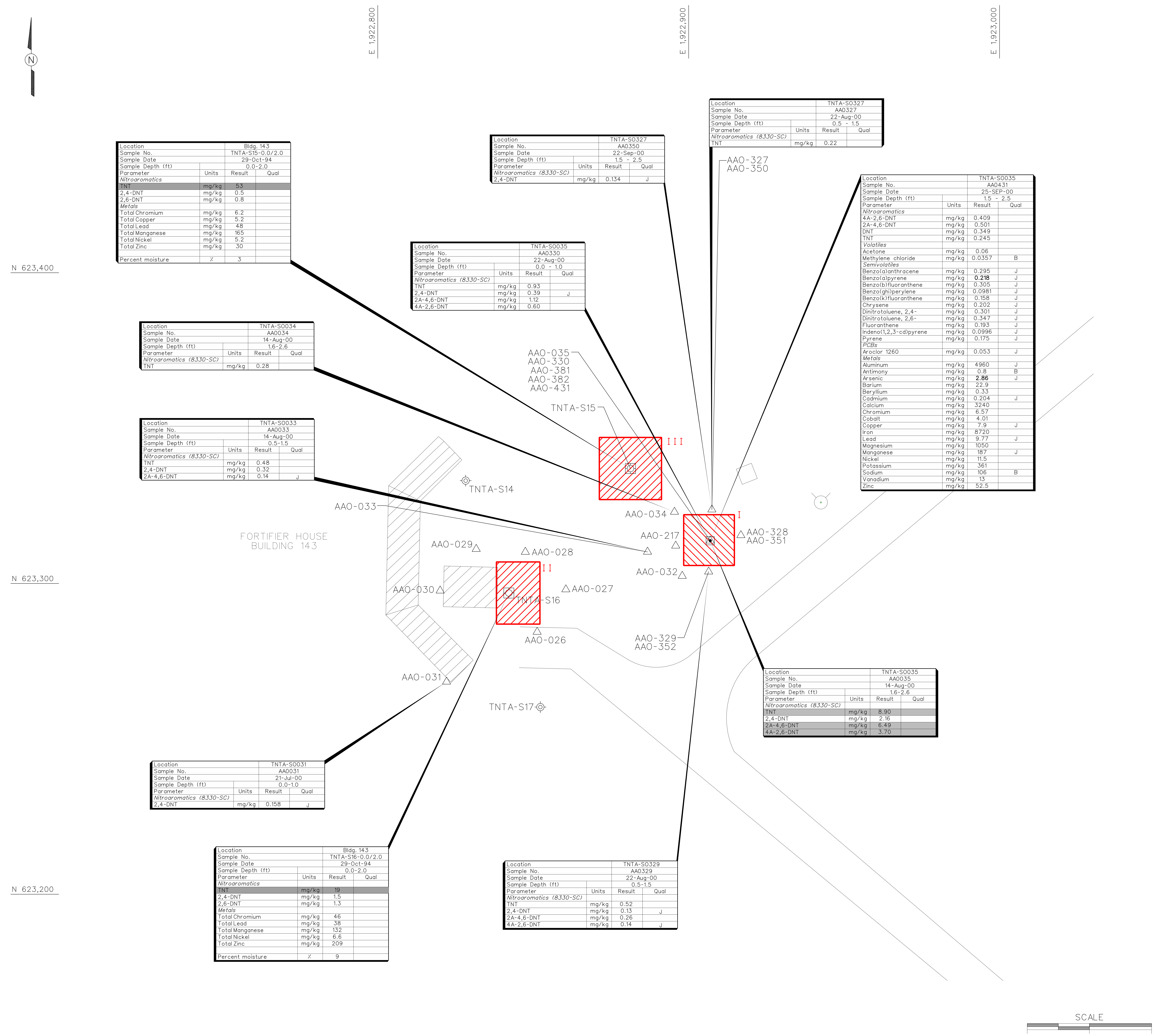
Table 5-1

Comparative Analysis of Remedial Alternatives
TNT Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and Off-Site Disposal	**Alternative 3:** Excavation and Off-Site Disposal	**Alternative 4:** Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal	**Alternative 5:** Excavation, Alkaline Hydrolysis, Chemical Stabilization, On-Site and Off-Site Disposal
Community Acceptance	Not acceptable	To be determined	To be determined	To be determined	To be determined

ARAR - Applicable or relevant and appropriate requirement.
COC - Contaminant of concern.
cy - Cubic yard.
mg/kg - Milligrams per kilogram.
O&M - Operation and maintenance.
OEPA - Ohio Environmental Protection Agency.
PAH - Polynuclear aromatic hydrocarbon.
RCRA - Resource Conservation and Recovery Act.
RG - Remedial goal.
ROD - Record of decision.
TNT - Trinitrotoluene.
TSDF - Treatment, storage, and disposal facility.
USEPA - U.S. Environmental Protection Agency.

FIGURES



Location		Bldg. 143	
Sample No.		TNTA-S15-0.0/2.0	
Sample Date		29-Oct-94	
Sample Depth (ft)		0.0-2.0	
Parameter	Units	Result	Qual
Nitroaromatics			
TNT	mg/kg	53	
2,4-DNT	mg/kg	0.5	
2,6-DNT	mg/kg	0.8	
Metals			
Total Chromium	mg/kg	6.2	
Total Copper	mg/kg	5.2	
Total Lead	mg/kg	48	
Total Manganese	mg/kg	165	
Total Nickel	mg/kg	5.2	
Total Zinc	mg/kg	30	
Percent moisture	%	3	

Location		TNTA-S0327	
Sample No.		AA0350	
Sample Date		22-Sep-00	
Sample Depth (ft)		1.5 - 2.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
2,4-DNT	mg/kg	0.134	J

Location		TNTA-S0327	
Sample No.		AA0327	
Sample Date		22-Aug-00	
Sample Depth (ft)		0.5 - 1.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.22	

Location		TNTA-S0035	
Sample No.		AA0330	
Sample Date		22-Aug-00	
Sample Depth (ft)		0.0 - 1.0	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.93	
2,4-DNT	mg/kg	0.39	J
2A-4,6-DNT	mg/kg	1.12	
4A-2,6-DNT	mg/kg	0.60	

Location		TNTA-S0035	
Sample No.		AA0431	
Sample Date		25-SEP-00	
Sample Depth (ft)		1.5 - 2.5	
Parameter	Units	Result	Qual
Nitroaromatics			
4A-2,6-DNT	mg/kg	0.409	
2A-4,6-DNT	mg/kg	0.501	
DNT	mg/kg	0.349	
TNT	mg/kg	0.245	
Volatiles			
Acetone	mg/kg	0.06	
Methylene chloride	mg/kg	0.0357	B
Semivolatiles			
Benzo(a)anthracene	mg/kg	0.295	J
Benzo(a)pyrene	mg/kg	**0.218**	J
Benzo(b)fluoranthene	mg/kg	0.305	J
Benzo(ghi)perylene	mg/kg	0.0981	J
Benzo(k)fluoranthene	mg/kg	0.158	J
Chrysene	mg/kg	0.202	J
Dinitrotoluene, 2,4-	mg/kg	0.301	J
Dinitrotoluene, 2,6-	mg/kg	0.347	J
Fluoranthene	mg/kg	0.193	J
Indeno(1,2,3-cd)pyrene	mg/kg	0.0996	J
Pyrene	mg/kg	0.175	J
PCBs			
Aroclor 1260	mg/kg	0.053	J
Metals			
Aluminum	mg/kg	4960	J
Antimony	mg/kg	0.8	B
Arsenic	mg/kg	**2.86**	J
Barium	mg/kg	22.9	
Beryllium	mg/kg	0.33	
Cadmium	mg/kg	0.204	J
Calcium	mg/kg	3240	
Chromium	mg/kg	6.57	
Cobalt	mg/kg	4.01	
Copper	mg/kg	7.9	J
Iron	mg/kg	8720	
Lead	mg/kg	9.77	J
Magnesium	mg/kg	1050	
Manganese	mg/kg	187	J
Nickel	mg/kg	11.5	
Potassium	mg/kg	361	
Sodium	mg/kg	106	B
Vanadium	mg/kg	13	
Zinc	mg/kg	52.5	

Location		TNTA-S0034	
Sample No.		AA0034	
Sample Date		14-Aug-00	
Sample Depth (ft)		1.6-2.6	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.28	

Location		TNTA-S0033	
Sample No.		AA0033	
Sample Date		14-Aug-00	
Sample Depth (ft)		0.5-1.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.48	
2,4-DNT	mg/kg	0.32	
2A-4,6-DNT	mg/kg	0.14	J

Location		TNTA-S0035	
Sample No.		AA0035	
Sample Date		14-Aug-00	
Sample Depth (ft)		1.6-2.6	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	8.90	
2,4-DNT	mg/kg	2.16	
2A-4,6-DNT	mg/kg	6.49	
4A-2,6-DNT	mg/kg	3.70	

Location		TNTA-S0031	
Sample No.		AA0031	
Sample Date		21-Jul-00	
Sample Depth (ft)		0.0-1.0	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
2,4-DNT	mg/kg	0.158	J

Location		Bldg. 143	
Sample No.		TNTA-S16-0.0/2.0	
Sample Date		29-Oct-94	
Sample Depth (ft)		0.0-2.0	
Parameter	Units	Result	Qual
Nitroaromatics			
TNT	mg/kg	19	
2,4-DNT	mg/kg	1.5	
2,6-DNT	mg/kg	1.3	
Metals			
Total Chromium	mg/kg	46	
Total Lead	mg/kg	38	
Total Manganese	mg/kg	132	
Total Nickel	mg/kg	6.6	
Total Zinc	mg/kg	209	
Percent moisture	%	9	

Location		TNTA-S0329	
Sample No.		AA0329	
Sample Date		22-Aug-00	
Sample Depth (ft)		0.5-1.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.52	
2,4-DNT	mg/kg	0.13	J
2A-4,6-DNT	mg/kg	0.26	
4A-2,6-DNT	mg/kg	0.14	J

LEGEND:

- AAO-027 — SCREENING SOIL SAMPLING LOCATION
- AAO-330 — SURFACE SOIL SAMPLE (0 - 1 FT)
- AAO-431 — CONFIRMATION SOIL SAMPLING LOCATION
- TNTA-S18 — HISTORICAL SOIL BORING LOCATION
- TNTA-S20 — HISTORICAL SOIL BORING LOCATION WITH EXPLOSIVES DETECTION
- FIRE HYDRANT
- FORMER TANK LOCATION
- FORMER BUILDING LOCATION
- POTENTIAL NITROAROMATIC REMEDIATION AREA
- ADDITIONAL POTENTIAL NITROAROMATIC REMEDIATION AREA IDENTIFIED IN THIS ADDENDUM

NOTES:

1. SAMPLES WITH NO POSTED DATA ARE BELOW QUANTITATION LIMITS FOR ALL NITROAROMATICS.
2. ALL CONFIRMATION SAMPLING LOCATIONS WERE SURVEYED.
3. NITROAROMATICS (8330-SC) INDICATES SCREENING ANALYSES.
4. SAMPLING DEPTHS

SAMPLE	DEPTH (FT)
AA0026	2.0 - 3.0
AA0027	1.6 - 2.6
AA0028	1.6 - 2.6
AA0029	2.0 - 3.0
AA0030	1.0 - 2.0
AA0031	0.0 - 1.0
AA0032	1.6 - 2.6
AA0033	0.5 - 1.5
AA0034	1.6 - 2.6
AA0035	1.6 - 2.6
AA0217	1.5 - 2.5
AA0327	0.5 - 1.5
AA0328	0.5 - 1.5
AA0329	0.5 - 1.5
AA0330	0.0 - 1.0
AA0350	1.5 - 2.5
AA0351	1.5 - 2.5
AA0352	1.5 - 2.5
AA0381	4.0 - 6.0
AA0382	8.0 - 10.0
AA0431	1.5 - 2.5
TNTA-S15	0.0 - 2.0
TNTA-S16	0.0 - 2.0

5. SHADED CONCENTRATIONS INDICATE DETECTIONS EXCEEDING RGOs.
6. ESTIMATED REMEDIAL VOLUME:

AREA NO.	AREA (FT^2)	DEPTH (FEET)	VOLUME (YD^3)
I	266	7	69

AREA NO.	AREA (FT^2)	DEPTH (FEET)	VOLUME (YD^3)
II	280	7	73
III	400	7	104

7. GROUNDWATER ENCOUNTERED AT 7 FEET IN SEPTEMBER 2000 BORING A-381/382. BORING DRILLED TO 10 FEET, BEDROCK NOT ENCOUNTERED (IT, 2001a).

FIGURE 1-17
PROPOSED REMEDIATION AREAS FOR BUILDING AREA 143
TNT AREA A

FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

Shaw® a world of Solutions™

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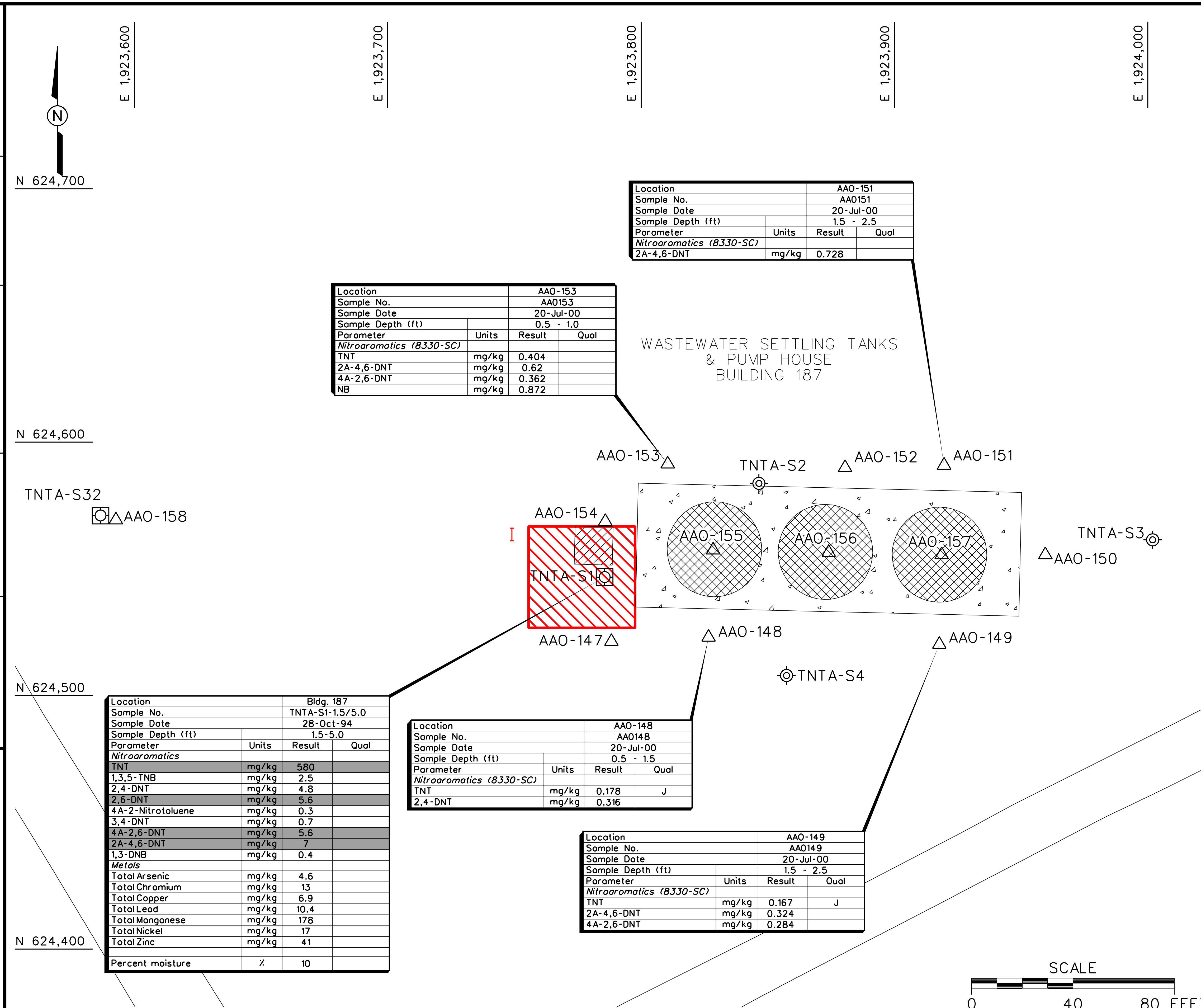
PBOW_standard.tbl



Location		AAO-151	
Sample No.		AA0151	
Sample Date		20-Jul-00	
Sample Depth (ft)		1.5 - 2.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
2A-4,6-DNT	mg/kg	0.728	

Location		AAO-153	
Sample No.		AA0153	
Sample Date		20-Jul-00	
Sample Depth (ft)		0.5 - 1.0	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.404	
2A-4,6-DNT	mg/kg	0.62	
4A-2,6-DNT	mg/kg	0.362	
NB	mg/kg	0.872	

Location		Bldg. 187	
Sample No.		TNTA-S1-1.5/5.0	
Sample Date		28-Oct-94	
Sample Depth (ft)		1.5-5.0	
Parameter	Units	Result	Qual
Nitroaromatics			
TNT	mg/kg	580	
1,3,5-TNB	mg/kg	2.5	
2,4-DNT	mg/kg	4.8	
2,6-DNT	mg/kg	5.6	
4A-2-Nitrotoluene	mg/kg	0.3	
3,4-DNT	mg/kg	0.7	
4A-2,6-DNT	mg/kg	5.6	
2A-4,6-DNT	mg/kg	7	
1,3-DNB	mg/kg	0.4	
Metals			
Total Arsenic	mg/kg	4.6	
Total Chromium	mg/kg	13	
Total Copper	mg/kg	6.9	
Total Lead	mg/kg	10.4	
Total Manganese	mg/kg	178	
Total Nickel	mg/kg	17	
Total Zinc	mg/kg	41	
Percent moisture	%	10	

Location		AAO-148	
Sample No.		AA0148	
Sample Date		20-Jul-00	
Sample Depth (ft)		0.5 - 1.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.178	J
2,4-DNT	mg/kg	0.316	

Location		AAO-149	
Sample No.		AA0149	
Sample Date		20-Jul-00	
Sample Depth (ft)		1.5 - 2.5	
Parameter	Units	Result	Qual
Nitroaromatics (8330-SC)			
TNT	mg/kg	0.167	J
2A-4,6-DNT	mg/kg	0.324	
4A-2,6-DNT	mg/kg	0.284	

LEGEND:

- △ AAO-147 — SCREENING SURFACE SOIL SAMPLING LOCATION
- TNTA-S2 — HISTORICAL SOIL BORING LOCATION
- TNTA-S1 — HISTORICAL SOIL BORING LOCATION WITH EXPLOSIVES DETECTION
- TANK
- BUILDING
- POTENTIAL NITROAROMATIC REMEDIATION AREA

NOTES:

1. SAMPLES WITH NO POSTED DATA ARE BELOW QUANTITATION LIMITS FOR ALL NITROAROMATICS.
2. ALL CONFIRMATION SAMPLING LOCATIONS WERE SURVEYED.
3. NITROAROMATICS (8330-SC) INDICATES SCREENING ANALYSES.
4. SAMPLING DEPTHS

SAMPLE	DEPTH (FT)
AA0147	2.0 - 3.0
AA0148	0.5 - 1.5
AA0149	1.5 - 2.5
AA0150	0.5 - 1.5
AA0151	1.5 - 2.5
AA0152	0.5 - 1.5
AA0153	0.5 - 1.0
AA0154	0.5 - 1.5
AA0155	0.5 - 1.5
AA0156	0.5 - 1.0
AA0157	0.5 - 1.0
AA0158	0.0 - 1.0
TNTA-S1	1.5 - 5.0

5. SHADED CONCENTRATIONS INDICATE DETECTIONS EXCEEDING RGOs.
6. BASED ON TOPOGRAHPY AND THE WATER TABLE DEPTHS OF THE NEAREST WELLS, IT IS EXPECTED THAT GROUNDWATER WOULD BE ENCOUONTERED AT A DEPTH OF NO GREATER THAN 10 FEET.
7. ESTIMATED REMEDIAL VOLUME:

AREA NO.	AREA (FT^2)	DEPTH (FEET)	VOLUME (YD^3)
I	1680	10	622

FIGURE 1-35

PROPOSED REMEDIATION AREA FOR BUILDING AREA 187, TNT AREA A

FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

Shaw® a world of Solutions™

fs_tnta_1-35.dgn
PROJ. NO.: 119268
INITIATOR: T. SIARD
PROJ. MGR.: S. DOWNEY
DRAFT. CHCK. BY:
ENGR. CHCK. BY:
DATE LAST REV.:
DRAWN BY:
STARTING DATE: 09/11/09
DRAWN BY: S. MCCAWLEY
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9/16/2009
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Figure 3-1

Cometabolic Reduction of 2,4,6-TNT During Fermentation of Glucose

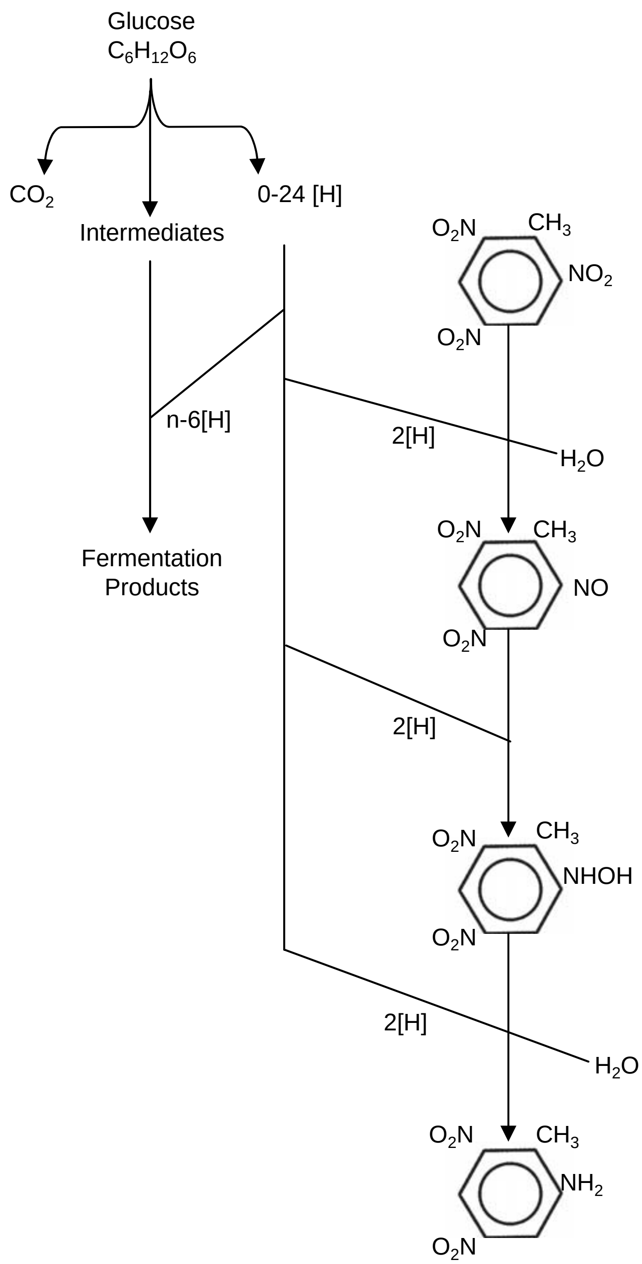
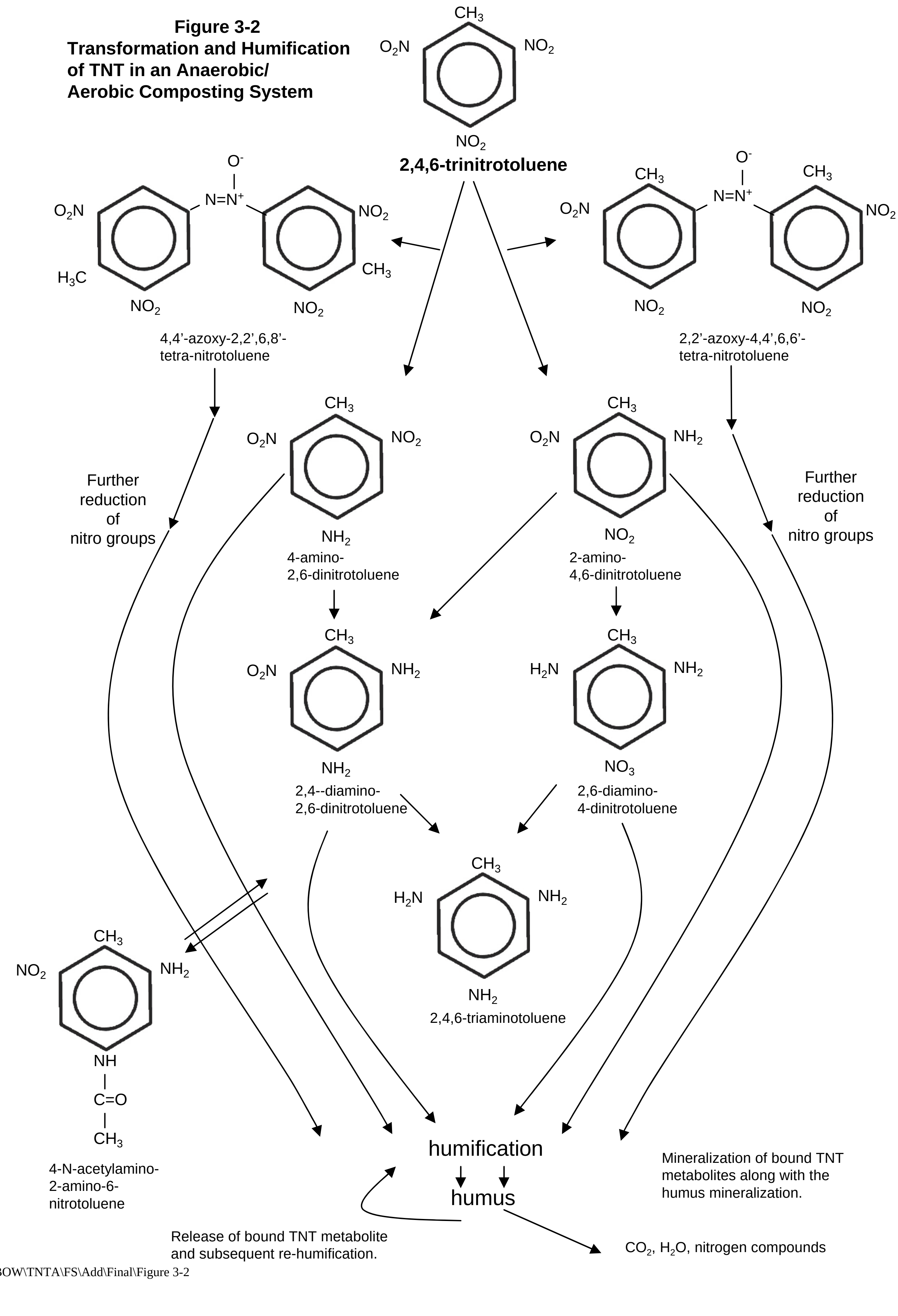


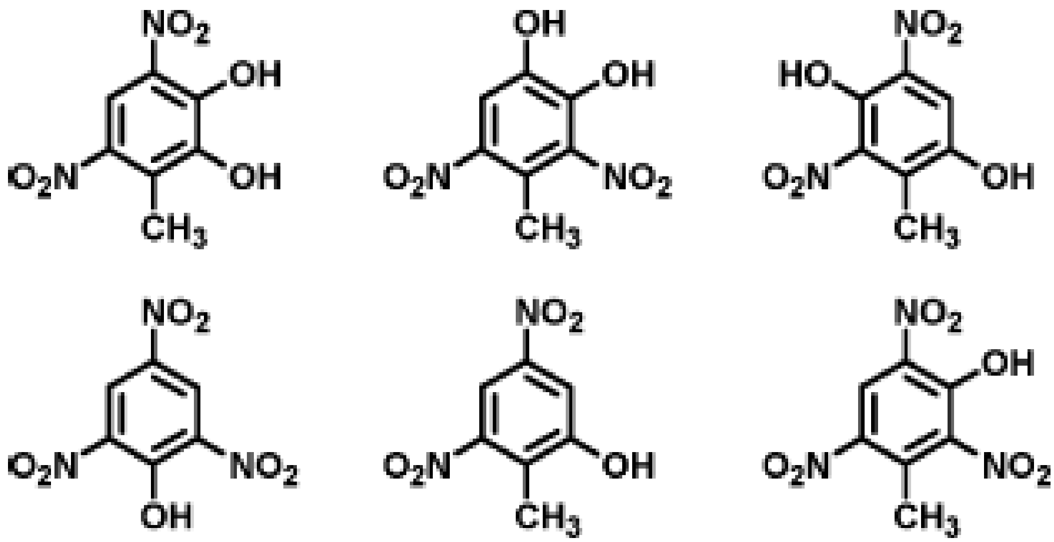
Figure 3-2
Transformation and Humification of TNT in an Anaerobic/ Aerobic Composting System



KN9\PBOW\TNTA\FS\Add\Final\Figure 3-2

Figure 3-3

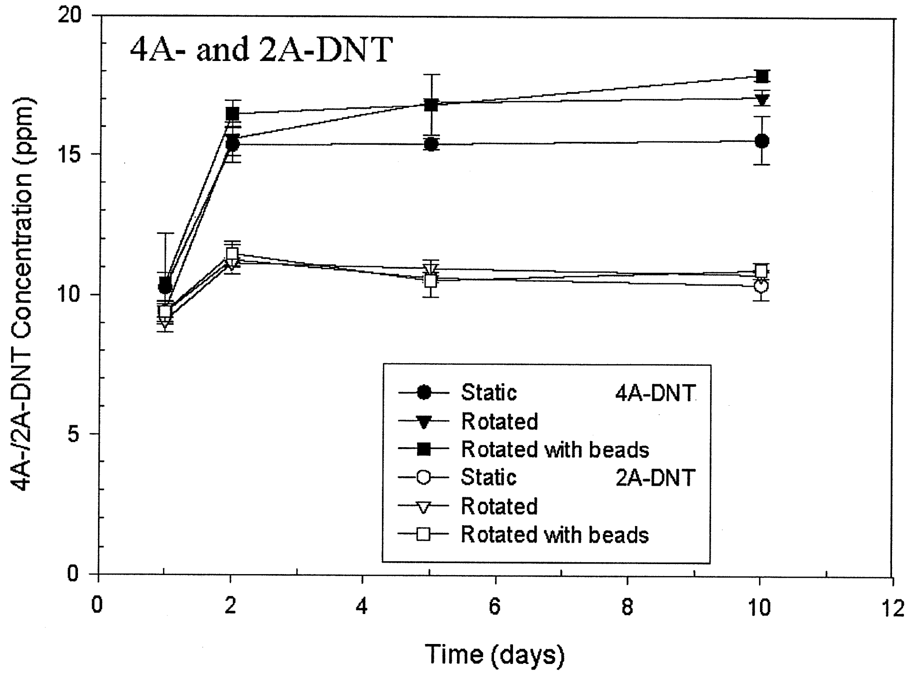
Structures from the Initial Attack of Hydroxide Ion on Trinitrotoluene



Reference: Thorn, K., P. Thorne, L. Cox, 2004, "Alkaline Hydrolysis/Polymerization of 2,4,6-Trinitrotoluene: Characterization of Products by 13C and 15N NMR," ***Environmental Science and Technology***, 38(7), 2224-2231.

Figure 3-4

Effect of Mixing Regime on Aminodinitrotoluene Concentrations in Trinitrotoluene-Contaminated Soil Treated with Lime



(Initial concentration of ADNT in soil not reported)

Reference: Hansen, L., S. Larson, J. Davis, J. Cullinane, C. Nestler, and R. Felt, 2003, ***Lime Treatment of 2,4,6-Trinitrotoluene Contaminated Soils: Proof of Concept Study***, ERDC/EL TR-03-15, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi, September.