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January 13, 2009

U.S. Army Engineer District, Nashville
ATTN: CELRN-EC-R (Ms. Kathy McClanahan)
110 Ninth Avenue South, Room 682
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Nashville, Tennessee 37203

Submittal of Draft Proposed Plan and
Final Focused Feasibility Study Addendum
TNT Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio
Contract No. DACA62-00-D-0002: Shaw Project Number 119268

Dear Ms. McClanahan:

In accordance with the requirements of Delivery Order No. DX02 of Contract No. DACA62-00-D-0002, Shaw is pleased to submit the following documents:

- Draft Proposed Plan for Soils and Sediment
- Final Focused Feasibility Study Addendum for Soils and Sediment.

Enclosed are four copies of each document. The Draft TNTC Proposed Plan is enclosed for your review, and the Final FFS Addendum is enclosed for your records.

Control copies of the report have been distributed as shown on the attached page, with only electronic copies being sent to the Center for Expertise. Also, an electronic copy of the Final Focused Feasibility Study (FFS) Addendum has been sent to the Huntington District, as requested, for their records.

Should you have any questions or require additional information regarding this submittal, please do not hesitate to contact me at (865) 694-7496.

Sincerely,

Steven T. Downey, PE
Project Manager

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Enclosures

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Final

Feasibility Study Addendum
TNT Area C
Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared by:

Shaw Environmental, Inc.
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January 2009

Table of Contents

Page

List of Tables iv
List of Figures iv
List of Acronyms v
Executive Summary ES-1
3.0 Screening of Remedial Action Technologies 3-1
3.3.4 Ex Situ Chemical Stabilization 3-1
3.3.4.1 Effectiveness 3-1
3.3.4.2 Implementability 3-1
3.3.4.3 Cost 3-1
3.3.4.4 Summary 3-1
3.3.6 Windrow Composting 3-2
3.3.6.1 Effectiveness 3-2
3.3.6.2 Implementability 3-7
3.3.6.3 Cost 3-7
3.3.6.4 Summary 3-7
3.3.7 Alkaline Hydrolysis 3-7
3.3.7.1 Effectiveness 3-7
3.3.7.2 Implementability 3-11
3.3.7.3 Cost 3-12
3.3.7.4 Summary 3-13
4.0 Development and Detailed Analysis of Remedial Alternatives 4-1
4.1 Introduction 4-1
4.2 Alternative 1-No Action 4-2
4.2.1 Description 4-2
4.2.2 Overall Protection of Human Health and the Environment 4-2
4.2.3 Compliance with ARARs 4-3
4.2.4 Long-Term Effectiveness 4-3
4.2.5 Reduction of Toxicity, Mobility, or Volume 4-3
4.2.6 Short-Term Effectiveness 4-3
4.2.7 Implementability 4-3
4.2.8 Cost 4-3
4.2.9 State Acceptance 4-3

Table of Contents *(Continued)*

Page

4.2.10 Community Acceptance 4-3
4.3 Alternative 2-Excavation, Windrow Composting, and Off-Site Disposal 4-3
4.3.1 Description 4-3
4.3.2 Overall Protection of Human Health and the Environment 4-5
4.3.3 Compliance with ARARs 4-6
4.3.4 Long-Term Effectiveness 4-6
4.3.5 Reduction of Toxicity, Mobility, or Volume 4-6
4.3.6 Short-Term Effectiveness 4-7
4.3.7 Implementability 4-7
4.3.8 Cost 4-8
4.3.9 State Acceptance 4-8
4.3.10 Community Acceptance 4-8
4.4 Alternative 3-Excavation and Off-Site Treatment/Disposal 4-8
4.4.1 Description 4-8
4.4.2 Overall Protection of Human Health and the Environment 4-9
4.4.3 Compliance with ARARs 4-10
4.4.4 Long-Term Effectiveness 4-10
4.4.5 Reduction of Toxicity, Mobility, or Volume 4-10
4.4.6 Short-Term Effectiveness 4-10
4.4.7 Implementability 4-11
4.4.8 Cost 4-11
4.4.9 State Acceptance 4-12
4.4.10 Community Acceptance 4-12
4.5 Alternative 4-Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal 4-12
4.5.1 Description 4-12
4.5.2 Overall Protection of Human Health and the Environment 4-13
4.5.3 Compliance with ARARs 4-13
4.5.4 Long-Term Effectiveness 4-13
4.5.5 Reduction of Toxicity, Mobility, or Volume 4-14
4.5.6 Short-Term Effectiveness 4-14
4.5.7 Implementability 4-15
4.5.8 Cost 4-16

Table of Contents *(Continued)*

Page

4.5.9 State Acceptance 4-16
4.5.10 Community Acceptance 4-16
4.6 Alternative 5-Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, and On-Site and Off-Site Disposal 4-16
4.6.1 Description 4-16
4.6.2 Overall Protection of Human Health and the Environment 4-19
4.6.3 Compliance with ARARs 4-19
4.6.4 Long-Term Effectiveness 4-19
4.6.5 Reduction of Toxicity, Mobility, or Volume 4-20
4.6.6 Short-Term Effectiveness 4-20
4.6.7 Implementability 4-21
4.6.8 Cost 4-22
4.6.9 State Acceptance 4-22
4.6.10 Community Acceptance 4-23
5.0 Comparative Analysis of Remedial Alternatives 5-1
5.1 Protection of Human Health and the Environment 5-1
5.2 Compliance with Applicable or Relevant and Appropriate Requirements 5-1
5.3 Long-Term Effectiveness and Permanence 5-1
5.4 Reduction of the Toxicity, Mobility, or Volume of Contamination 5-1
5.5 Short-Term Effectiveness 5-2
5.6 Implementability 5-2
5.7 Cost 5-3
5.8 State Acceptance 5-3
5.9 Community Acceptance 5-3
6.0 References 6-1

List of Tables

Table	Title	Follows Text
3-1	Effectiveness of Lime Treatment on Soil Contaminated with Nitroaromatic Explosive Compounds	
3-2	Partial Summary of Pilot Test Results for Alkaline Hydrolysis with Caustic Soda	
3-3	Summary of Alkaline Hydrolysis Treatability Study Results	
4-2	Alternative 2 Cost Estimate, TNT Area C	
4-4	Alternative 3 Cost Estimate, TNT Area C	
4-6	Alternative 4 Cost Estimate, TNT Area C	
4-8	Alternative 5 Cost Estimate, TNT Area C	
5-2	Comparative Analysis of Remedial Alternatives	

List of Figures

Figure	Title	Follows Text
3-1	Cometabolic Reduction of 2,4,6-TNT During Fermentation of Glucose	
3-2	Transformation and Humification of TNT in an Anaerobic/Aerobic Composting System	
3-3	Structures from the Initial Attack of Hydroxide Ion on Trinitrotoluene	
3-4	Effect of Mixing Regime on Aminodinitrotoluene Concentrations in Trinitrotoluene-Contaminated Soil Treated with Lime	

List of Acronyms

ADNT	aminodinitrotoluene
ARAR	applicable or relevant and appropriate requirement
CFR	Code of Federal Regulations
COC	chemical of concern
cy	cubic yard
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
ºC	degrees Celsius
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
TNTC	TNT Area C
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 (TNTC) 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 TNTC only; a separate addendum will be prepared for TNTA.

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 TNTC 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 TNTC 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 and sediment that require remedial action at TNTC.

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

- Ex situ 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 are based on in-place or consolidated soil and do not account for changes in volume due to excavation or treatment. Note that the associated costs consider these 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.*** This alternative consists of excavation of contaminated soil (9,205 cubic yards): windrow composting of soil that would be a hazardous waste due to elevated concentrations of 2,4-dinitrotoluene (DNT) (2,103 cubic yards); off-site treatment and/or disposal of lead-contaminated soil (400 cubic yards) at a Subtitle C hazardous waste treatment, storage, and disposal facility; and off-site disposal of composted soil and the remaining untreated soil in an approved solid waste landfill (8,805 cubic yards).

- ***Alternative 3 – Excavation and Off-Site Disposal.*** This alternative consists of excavation of contaminated soil (9,205 cubic yards), disposal of nonhazardous soil (6,805 cubic yards) at an approved solid waste landfill, and off-site treatment and/or disposal of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT or lead (2,310 cubic yards) at a Subtitle C hazardous waste transportation, storage, and disposal facility.

- ***Alternative 4 - Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal.*** This alternative consists of excavation of contaminated soil (9,205 cubic yards), windrow composting of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT (2,103 cubic yards), ex situ chemical stabilization of soil that would be a hazardous waste due to elevated concentrations of lead (400 cubic yards), and off-site disposal of all treated and untreated soil in an approved solid waste landfill (9,205 cubic yards).

- ***Alternative 5 - Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, On-Site and Off-Site Disposal.*** This alternative consists of excavation of contaminated soil (9,205 cubic yards), alkaline hydrolysis of soil that would be a hazardous waste due to elevated concentrations of 2,4-DNT (2,103 cubic yards), windrow composting of alkaline hydrolysis treated soil that is not acceptable for disposal back on site due to elevated

concentrations of nitroaromatic chemicals of concern (420 cubic yards), ex situ chemical stabilization of soil that would be a hazardous waste due to elevated concentrations of lead (400 cubic yards), on-site disposal of all alkaline hydrolysis and composted soil not treated for lead (1,910 cubic yards), and off-site disposal of all untreated soil and lead-stabilized soil in an approved solid waste landfill (7,295 cubic yards).

The revised comparative analysis in Chapter 5.0 of this report recommends that *Alternative 6: Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, and On-Site and Off-Site Disposal*, should be selected as the preferred remedial alternative for TNTC as described in revised Section 5.10. The alternative meets the threshold criteria of protection of human health and the environment and compliance with applicable or relevant and appropriate requirements. Alternative 5 is the most cost-effective alternative based on an evaluation of the five balancing criteria used in the feasibility study process. The evaluation of remedial alternatives with respect to the two modifying criteria, state and community acceptance, will be presented after the public has had an opportunity to comment on the Proposed Plan.

Alternative 5 is recommended over Alternative 3 because it utilizes on-site treatment to satisfy the statutory preference for alternatives that reduce the toxicity, mobility, or volume of contamination through treatment. Alternative 3 does not utilize on-site treatment. Alternative 5 is also less costly than Alternative 4. Both alternatives provide equal protection for human health and the environment.

Alternative 5 is recommended over Alternatives 2 and 4 because Alternative 5 provides equal protection for human health and the environment and is less costly to implement.

Alternative 5 is recommended over Alternative 1 because Alternative 1 does not protect human health and the environment.

The total present value cost (including 30 percent contingency) for each of the 5 remedial alternatives is provided in the following table. Alternative 5 has the lowest remedial cost of all the alternatives evaluated ($2.4 million). The remedial cost for Alternative 5 would be lower by approximately $74,000 if the alkaline hydrolysis-treated soil does not need to be neutralized prior to off-site disposal.

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
$0	$3.3 million	$2.9 million	$3.2 million	$2.4 million

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 TNTC, 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 alternative land disposal restriction (LDR) treatment standards for contaminated soil. However, the alternative LDR 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. Because 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 chemical 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 and PAHs. 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 or sediment. 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°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 functions, and 2 percent as nitro functions.

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. Furthermore, 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 cy. 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 cy 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), and 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 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 and 60°C for optimum treatment efficiency. Microbial activity is substantially reduced at temperatures above 71°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 FFS.

Windrow composting could be an effective treatment process to achieve RAOs for nitroaromatic compounds and PAHs in soil at TNTC. The 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 that 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.

3.3.6.2 Implementability

This process is technically and administratively implementable at TNTC. 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 TNTC 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 mg/kg 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 TNTC, with the exception of 2,6-DNT, although the final concentration of total DNTs in the treated soil would have been below the combined TNTC RG for DNTs in all three treatments. It is notable that the starting concentrations of DNTs in the VAAP treatability test were much higher that the MDC in soil at TNTC, so it is possible that the treatments could have attained the individual RG for 2,6-DNT using the less contaminated PBOW soil as a test media. The 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. 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; therefore, the soil was spiked prior to treatment. Several alkaline reagents were tested and sodium hydroxide was found to be the most effective reagent. The treatability study confirmed that treatment 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 just 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. Table 3-3 shows that the maximum detected concentrations of both 2,4-DNT and 2,6-DNT in TNTC soil are below the alternative LDR treatment standards. Therefore, the LDR requirements would not prohibit disposal of treated soil for the concentrations typically detected at the site.

Although none the treatability tests were sufficiently effective for all nitroaromatic constituents, alkaline hydrolysis might still be an effective treatment for soil contaminated with DNT at concentrations within the range detected at TNTC. The maximum concentrations of 2,4-DNT and 2,6-DNT detected at TNTC are 275 mg/kg and 65.5 mg/kg, respectively. The concentrations of DNTs in the spiked samples were much higher (10,733 mg/kg 2,4-DNT and 11,441 mg/kg 2,6-DNT) because these concentrations are representative of contamination at TNTA and the treatability study was designed so that the results would be applicable to both sites.

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 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 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 cy 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 cy 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 offsite as a non-hazardous waste without neutralization. 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 cy 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 ≤ pH ≤ 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 TNTC 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 TNTC.

The following six 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 or sediment at TNTC.

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 ARAR for soil or sediment. 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 TNTC 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 TNTC 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 in a RCRA Subtitle C treatment, storage, and disposal facility (TSDF).

The treatment area previously prepared at PBOW for windrow composting will be used for alkaline hydrolysis and composting operations. The composting treatment area is 800 feet long by 260 feet wide and surrounded by an earthen berm to contain storm water runoff. Treatment operations will 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 will be constructed within the treatment area and stockpiles of amendments, untreated soil and treated compost will be staged in the area.

Storm water will 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 will be applied to the windrows as needed to maintain the moisture content of the compost. Excess water will be trucked off site to an industrial wastewater treatment facility. No on-site treatment of contact water will be required.

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

Amendments will be brought to the facility as needed so that large amounts of amendments are not 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 will be available locally.

It is assumed that the compost will 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 will 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 will be staggered so that the windrows do not complete the treatment cycle at the same time.

The compost will 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 will consist of sampling the compost immediately after formation and one a week during treatment. One composite sample will 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 have 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 will be collected per windrow. The actual sampling and analytical strategy employed during remediation will be subject to negotiation between the OEPA and the USACE.

Untreated soil that passes the TCLP test will be disposed off site at an approved nonhazardous waste landfill. Composted soil that passes the TCLP test and complies with all LDR requirements will be disposed off site at an approved nonhazardous waste landfill. Segregated lead contaminated soil that does not pass the TCLP test will be managed as a D008 hazardous waste. The soil will be transported to an approved and permitted Subtitle C TSDF for treatment (if necessary to comply with the alternative LDR treatment standards for contaminated soil) and disposal.

4.3.2 Overall Protection of Human Health and the Environment

Alternative 2 will 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 will lower 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 concentrations of 2,4-DNT will be biologically treated via windrow composting to render it nonhazardous for disposal.

4.3.3 Compliance with ARARs

The alternative will comply with all ARARs. There are no chemical-specific ARARs for soil or sediment. 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 will 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 COCs 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 will 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 will also reduce the mass transport of soil contaminants to groundwater.

The alternative will 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 will 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 will reduce the toxicity and mobility of nitroaromatic compounds and PAHs in soil through a combination of biological degradation and immobilization via covalent binding with humic substances in the compost.

Under this alternative, 8,805 cy of treated and untreated soil (consolidated basis) with be managed for disposal at an approved non-hazardous waste landfill and 400 cubic yards of lead-contaminated soil (consolidated basis) will be disposed of in a Subtitle C TSDF (treatment may be required at the TSDF to comply with land disposal restrictions). Table 2-9 (see 2003 Final FFS) provides a detailed breakdown of excavated soil volumes on a site-by-site basis.

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 will 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 will be managed to minimize the generation of dust or nuisance odors during remediation. Proper decontamination and waste transportation practices will be followed to prevent the spread of contamination when equipment or waste materials leave the site.

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

Environmental impacts during remediation will be mitigated primarily through measures designed to ensure that contamination is not spread during remedial activities. These measures include 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 16 to 22 months will be required to complete remedial activities under Alternative 2 at TNTC in one field event, from the initiation of work plans to backfilling excavated areas and disposal of excavated soil and treatment residuals. Table 4-2 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 COCs 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 will be utilized during precompliance testing to augment analytical work in off-site laboratories to lower analytical costs. Standard fixed-base laboratory analyses will be used for final compliance sampling after treatment is complete for each batch of compost. The treatment process can be extended for any composted material that fails compliance testing.

The alternative does not preclude additional future 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 TNTC is presented in Table 4-2. The estimated capital cost for Alternative 2 is $3.3 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 will 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 TNTC. No on-site treatment will 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 and sediment from TNTC is 9,205 cy. Once this soil is excavated, the total volume of unconsolidated material is estimated to be 11,967 cy (30 percent swell).

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

Following excavation of the contaminated soil, representative soil samples from each area will be analyzed using the TCLP test. Based on existing soil data from TNTC, the unconsolidated volume of excavated soil that may be classified as a characteristic hazardous waste due to 2,4-DNT and lead concentrations is estimated at 2,310 cy. The volume of RCRA hazardous waste is estimated to be 25 percent of the total excavated soil.

Section 2.5.1 of the FFS (Shaw, 2003) summarizes the applicable regulations used to determine if the excavated soil is a hazardous waste. Soil that passes the TCLP test and complies with all LDR requirements can be disposed in a nonhazardous waste landfill. Therefore, it is estimated that, of the 9,205 cy of soil and sediment that will be excavated under this approach, 6,895 cy can be shipped for disposal at a solid waste landfill. The remaining 2,310 cy will be manifested and shipped for disposal at an off-site hazardous waste TSDF. The TSDF will treat any waste material that does not comply with the LDR treatment standards prior to disposal.

4.4.2 Overall Protection of Human Health and the Environment

Alternative 3 will 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 will 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 by disposing of the contaminated soil in a disposal facility designed, constructed, and maintained to permanently manage such waste materials. Once the contaminated soil is excavated, soil classified as hazardous based on TCLP testing will be disposed of in a RCRA

hazardous waste TSDF. Nonhazardous soil will be disposed of in a solid waste landfill approved by OEPA.

4.4.3 Compliance with ARARs

The alternative will comply with all ARARs. There are no chemical-specific ARARs for soil or sediment. 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 will be effective in protecting potential receptors from direct exposure to COCs in soil. The removal of the most highly contaminated soil will also reduce the mass transport of soil contaminants to groundwater.

The alternative will 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 will reduce the mass and volume of contaminated media remaining at the site, no net reductions in contaminant mass will be achieved unless a process such as incineration is performed at the TSDF, because COCs are transferred from one location to another. As a result**,** Alternative 3 will 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 will restrict the mobility of COCs in excavated soil.

4.4.6 Short-Term Effectiveness

The implementation of Alternative 3 will not present any significant health threats to the community. The excavation of contaminated soils will 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 will 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 will be performed prior to the commencement of the removal action, and a health and safety plan will be followed during site activities to ensure that risks to workers are minimized. Remediation workers will 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 10 to 16 months would be required to complete remedial activities, from the initiation of work plans to disposal of contaminated soil and backfilling excavated areas. Table 4-6 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 future 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 TNTC is presented in Table 4-4. The estimated capital cost for Alternative 3 is $2.9 million. The contingency capital cost allowance for Alternative 3 is 30 percent. This contingency accounts for the uncertainty in the estimated volume of soil requiring remediation and an allowance for

unidentified cost elements not incorporated in the estimate. There are no long-term O&M costs associated with this alternative. Therefore, the present value of this alternative is the same as its 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 Subtitle D landfill. This alternative is similar to Alternative 2, with the exception that lead-contaminated soil under Alternative 2 would not be treated on site, but would be disposed of off site as a hazardous waste in a RCRA Subtitle C TSDF. Approximately 9,205 cy of consolidated soil would be excavated, with 2,310 cy of consolidated soil treated using windrow composting and 400 cy of consolidated soil chemically stabilized.

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 will be composted first and then chemically stabilized. Composting should not interfere with the lead stabilization process as long as chemical stabilization is performed after composting.

Lead contaminated soil under this alternative will 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 will 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 will 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 will be biologically treated via windrow composting to render it nonhazardous for disposal. Soil with elevated lead concentrations will be chemically stabilized to render it nonhazardous. Treated and untreated soil that complies with LDR requirements and that is not a hazardous waste will be disposed of off site as a nonhazardous waste in a Subtitle D landfill.

4.5.3 Compliance with ARARs

The alternative will comply with all ARARs. There are no chemical-specific ARARs for soil or sediment. 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 will 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 will be effective in protecting potential receptors from direct exposure to COCs in soil. The removal of the most highly contaminated soil will also reduce the mass transport of soil contaminants to groundwater.

The alternative will 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 will 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 will reduce the toxicity and mobility of nitroaromatic compounds and PAHs 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, 9,205 cy of treated and untreated soil will be managed for disposal at an approved nonhazardous waste landfill.

4.5.6 Short-Term Effectiveness

The implementation of Alternative 4 will not present any significant health threats to the community. The excavation and treatment of contaminated soils will 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 will be managed to minimize the generation of dust or nuisance odors during remediation. Proper decontamination and waste transportation practices will 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 will be performed prior to the commencement of the removal action, and a health and safety plan will be followed during site activities to ensure that risks to workers are minimized. Remediation workers will be supplied with any protective gear required to conduct operations in a safe manner.

Environmental impacts during remediation will 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 and treatment, decontamination procedures for equipment and personnel, and storm water run-off and run-on controls.

It is estimated that 16 to 22 months will 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 4-6 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 will be used for final compliance sampling after treatment is 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 does not pass the TCLP test, the soil could be reprocessed.

The alternative does not preclude additional future 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 will 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 TNTC is presented in Table 4-6. The estimated capital cost for Alternative 4 is $3.2 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 as a nonhazardous waste in a Subtitle D landfill. Approximately 9,205 cy of consolidated soil will be excavated, with 2,310 cy of consolidated soil treated using alkaline hydrolysis/windrow composting and 400 cy of consolidated soil chemically stabilized.

Soil within the remediation areas will 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 will be trucked to the treatment area for screening. The screened soil will be stockpiled at the treatment facility for treatment or disposal. Soil adhering to the

oversize material will be removed so that the oversize material can be returned to the excavation. Any oversize material not appropriate for use as backfill will 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 alkaline hydrolysis treatability study. Alkaline hydrolysis will be implemented by adding caustic soda and ferric chloride to the excavated soil. The soil will be neutralized before placement back on site. NAC-contaminated soil will be treated in 300 cy batches, approximately 52 feet square by 3 feet deep per treatment cell. It is estimated that the remediation field crew could have 4 to 5 treatment cells in process at the same time within the treatment area. Nine or 10 batches will be required to complete treatment at TNTC. Approximately 61 pounds of caustic soda will be required per cy of soil. Caustic soda pellets will be spread across the soil in the treatment cell and mixed into the soil using an excavator and/or wheel loader. Water is 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 cy of soil. The batch of soil is turned every other day and moisture is 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 is 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 pound of ferrous sulfate will be required to neutralize all the caustic soda applied to the soil based on the treatability study results.

Alkaline hydrolysis-treated soil that does not pass the TCLP test for 2,4-DNT or that does not comply with remedial goals or alternative LDR requirements for nitroaromatic constituents in contaminated soil will be treated via windrow composting until compliance is attained. The goal of alkaline hydrolysis/windrow composting treatment is to allow the treated soil to be placed back on site. Soil that cannot be treated to remedial goals for all COCs will be managed as a nonhazardous waste for off-site disposal provided it passes TCLP and complies with LDR requirements. For cost estimating purposes, it is assumed that 20 percent of the alkaline hydrolysis-treated soil will be composted. The composting operation will be similar to that described for Alternative 2, and additional details about the operation are presented in Section 4.3.1.

Lead-contaminated soil under this alternative will be chemically stabilized using the Maectite process developed by Sevenson Environmental Services, Inc. Maectite is a more 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. Chemical stabilization of lead-contaminated soil will take place after either alkaline hydrolysis or composting if needed to reduce the concentration of nitroaromatic compounds or PAHs. Alkaline hydrolysis and composting should not interfere with the lead stabilization process as long as chemical stabilization is performed after these other treatment operations. Alkaline hydrolysis may promote stabilization of lead in the soil because the solubility of lead typically decreases with increasing pH.

The treatment area previously prepared at PBOW for windrow composting will be used for alkaline hydrolysis, composting, and stabilization operations. The treatment cells will be constructed within the treatment area and stockpiles of treated and untreated soil will be staged in the area. Storm water will 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 will be applied to the soil as needed to maintain the moisture content during treatment. Excess water will be trucked off site to an industrial wastewater treatment facility. No on-site treatment of contact water will 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 will be performed in two phases. The first phase takes place at the end of treatment with caustic soda and ferric chloride (~ day 7). A composite sample will be collected from each 300-cy batch and analyzed for total NACs, nitrate/nitrite, and TCLP 2,4-DNT. The second phase of compliance testing will be performed at the end of soil neutralization (~ day 10). A composite sample will be collected from each 300-cy batch and analyzed for pH (field test) and nitrate/nitrite (off-site laboratory).

Precompliance testing of the compost will consist of sampling the compost immediately after formation and once a week during treatment. One composite sample will 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 have been achieved, compliance samples will 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 will be collected per windrow. The actual sampling and analytical strategy employed during remediation will be subject to negotiation between the OEPA and the USACE.

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 will be subject to negotiation between the OEPA and the USACE.

4.6.2 Overall Protection of Human Health and the Environment

Alternative 5 will 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 will 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 will be chemically treated via alkaline hydrolysis to render it nonhazardous for disposal. Alkaline hydrolysis treated soil that does not pass the TCLP test for 2,4-DNT or that does not comply with remedial goals or LDR requirements for nitroaromatic constituents will be treated via windrow composting until compliance is attained. Soil with elevated lead concentrations will be chemically stabilized to render it nonhazardous. Alkaline hydrolysis and composted soil that meets remedial goal and LDR requirements will be placed back on site. Untreated soil and lead stabilized 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.

4.6.3 Compliance with ARARs

The alternative will comply with all ARARs. There are no chemical-specific ARARs for soil or sediment. 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 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 will be effective in protecting potential receptors from direct exposure to COCs in soil. The removal of the most highly contaminated soil will also reduce the mass transport of soil contaminants to groundwater.

The alternative will 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 will 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 will 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, 7,295 cy of treated and untreated soil will be managed for disposal at an approved non-hazardous waste landfill.

4.6.6 Short-Term Effectiveness

The implementation of Alternative 5 will not present any significant health threats to the community. The excavation and treatment of contaminated soil will 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 will be managed to minimize the generation of dust or nuisance odors during remediation. Proper decontamination and waste transportation practices will be followed to prevent the spread of contamination when equipment or waste materials leave 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 will be performed prior to the commencement of the removal action, and a health and safety plan will be followed during site activities to ensure that risks to workers are minimized. Remediation workers will be supplied with any protective gear required to conduct operations in a safe manner.

Environmental impacts during remediation will 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 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 will be segregated during storage, and best management practices will be followed to prevent the uncontrolled release of chemicals to the environment.

It is estimated that 16 to 22 months will 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 4-8 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). The technology is not effective with PAHs, although only about 450 of the 9,205 cy of excavated soil are contaminated with PAHs above RGs. 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 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 will determine final compliance of the treated soil. The alkaline hydrolysis treated soil must pass TCLP for 2,4-DNT, remedial goals for all COCs and alternative LDR treatment standards for underlying hazardous constituents in soil.

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 will be utilized during precompliance testing to augment analytical work in off-site laboratories to lower analytical costs. Standard fixed-base laboratory analyses will be used for final compliance sampling after treatment is complete for each batch of compost. The treatment process can 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 TNTC). Under either of the treatment processes, treated soil could be reprocessed until compliance levels are met. Alternately, the treated soil could be disposed offsite in a Subtitle C TSDF as a hazardous waste.

The alternative does not preclude additional future 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 will 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 TNTC is presented in Table 4-8. The estimated capital cost for Alternative 5 is $2.4 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 TNTC. A summary of this comparative analysis is presented in Table 5-2.

5.1 Protection of Human Health and the Environment

All of the alternatives, with the exception of Alternative 1, will 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 Applicable or Relevant and Appropriate Requirements

All of the alternatives, with the exception of Alternative 1, will comply with the location- and action-specific ARARs. There are no chemical-specific ARARs for soil or sediment. Location- and action-specific ARARs are not applicable for Alternative 1 because no action will be taken.

5.3 Long-Term Effectiveness and Permanence

All of the alternatives, with the exception of Alternative 1, will reduce the magnitude of residual risk at the site to levels within the risk management range. No long-term controls will 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 will 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 will treat about 25 percent of the contaminated soil excavated from TNTC. Alternative 3 will not employ any on-site treatment, although off-site treatment of some contaminated soil will 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, PAHs, 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 will remove contamination from the site, it will not result in any reduction of contaminant mass. The disposal of excavated soil in an appropriate TSDF will minimize the potential for contaminants to leach into the environment. Alternative 1 will have no effect on the toxicity, volume, or mobility of soil contamination.

5.5 Short-Term Effectiveness

Alternatives 2 through 5 will all provide adequate safeguards for site workers and the community during remediation. All the contaminated soil excavated under Alternatives 2 through 5 will require off-site management. Short-term effectiveness is not relevant to Alternative 1 because no action will be taken. No threatened or endangered animal or plant species will be significantly affected or destroyed by remedial actions at TNTC. In the event threatened and/or endangered plant species are later discovered in the proposed remediation areas, care will be taken to minimize disturbance. There will be short-term disturbances to ecological habitat as a result of the proposed remediation; however, the re-establishment of vegetative cover following the action will 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 TNTC are presented in Table 5-2. Alternative 3 will be completed within the shortest period of time, requiring approximately 10 to 16 months. Alternatives 2, 4 and 5 will take 16 to 22 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 will require the approval of OEPA for disposal of material off site. None of the alternatives will preclude additional actions if the technologies are not completely effective.

5.7 Cost

Alternative 1 is the lowest cost alternative. Alternative 5 has the lowest cost of the alternatives that employ remedial action. The remaining alternatives are ranked from lowest to highest cost: Alternative 3, Alternative 4, and Alternative 2.

Remedial costs for TNTC are presented in Table 5-2.

5.8 State Acceptance

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

5.9 Community Acceptance

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

6.0 References

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TABLES

Table 3-1

Effectiveness of Lime Treatment on Soil Contaminated with Nitroaromatic Explosive Compounds
TNT Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

	HTNT2[1]					ELBP2[2]				
Chemical	Untreated (mg/kg)	Treated[3] @ pH 11 (mg/kg)	Removal (%)	Treated[3] @ pH 12 (mg/kg)	Removal (%)	Untreated (mg/kg)	Treated[3] @ pH 11 (mg/kg)	Removal (%)	Treated[3] @ pH 12 (mg/kg)	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: Table 1 (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 Pilot Test Results for Alkaline Hydrolysis with Caustic Soda
TNT Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Units	PBOW MDC	PBOW 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	41621	8.0			8000 D	0.05 U	8000 D	0.05	8000 D	3.9
2,4-Dinitrotoluene	mg/kg	275	6.5	2.6	1400	2900 D	0.52 P	2900 D	1.2	2900 D	0.63
2,6-Dinitrotoluene	mg/kg	65.5	1.0		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		-			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		-			50 UD	0.77 P	50 UD	1.4 P	50 UD	0.76
2-Amino-4,6-Dinitrotoluene	mg/kg	38	1.7			50 UD	0.05 U	50 UD	0.05 U	50 UD	0.05 U
4-Amino-2,6-Dinitrotoluene	mg/kg	14.6	1.3			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

Source: ***Summary of Bench Scale and Field Treatability Tests, Chemical Treatment of TNT- and DNT-Contaminted Soil, TNT Manufacturing Valley, Volunteer Army Ammunition Plant, Chatanooga, 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
TNTC Manufacturing Area
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.		2588	65.5	275	67	44
RG		8	1.0	6.5	1.3	1.7
Min ATS	pH	-	280	1400	-	-
After 7-day treatment						
Control[a]	7.80	2575	11441b	10733b	11	4
Na2CO3	10.60	287	6916	6193	16	10
Na2CO3/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

Notes:
RG = remedial goal
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 4-2

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

Alternative 2
Excavation/Composting/Off-Site Disposal and Site Restoration
Cost Estimate

Site: TNT Area C
Plum Brook Ordnance Works
Date: 10/31/2008

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**

Table 4-2

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

3.0 Site Preparation

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

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 =	9205
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	11967
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	13163
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 =	24
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 =	40
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 =	286
21. Excavation area (ft^2) =	35583
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 =	3
26. Days screening crew in Level C =	2
27. Perimeter of excavation area (ft) =	3415
28. Excavation area (sf) =	35583
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	192	$49.00	/hr	$9,408.00
QA (Sampling) Coordinator	192	$36.00	/hr	$6,912.00
H&S Coordinator	192	$49.00	/hr	$9,408.00
Chemist (home office)	48	$51.00	/hr	$2,448.00
Equipment Operator	24	$406.00	/day	$9,744.00
Equipment Operator	20	$406.00	/day	$8,120.00
Equipment Operator	20	$406.00	/day	$8,120.00
Laborers	44	$341.60	/day	$15,030.40
Truck Drivers	48	$341.60	/day	$16,396.80

Table 4-2

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

4.0 Excavation of Contaminated Soil (continued)

Equipment:					
Excavator	2	$4,000.00	/mo	$8,000.00	
100-ton/hr Screening Plant	4	$1,800.00	/wk	$7,200.00	
Radial Stacking Conveyor	4	$1,222.00	/wk	$4,888.00	
Dozer	1	$3,500.00	/mo	$3,500.00	
Dump Truck	2	$3,890.00	/mo	$7,780.00	
Dump Truck	2	$3,890.00	/mo	$7,780.00	
3000 gal. Water Truck	24	$402.00	/day	$9,648.00	
21,000 gal Frac Tank	8	$1,400.00	/mo	$11,200.00	
150 gpm Pump	2	$2,439.00	/ea.	$4,878.00	
300 gpm Pump	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	
Analytical:					
TCLP Extraction	40	$12.88	/ea	$515.00	
SVOCs (8270C)	326	$300.00	/ea	$97,800.00	
NACs (8330)	326	$197.50	/ea	$64,385.00	
Lead	326	$30.00	/ea	$9,780.00	
PCBs	326	$103.75	/ea	$33,822.50	
NAC field analyses	286	$40.00	/ea	$11,440.00	
Lead field analyses	2	$4,200.00	/mo.	$8,400.00	
Shipping	87	$40.00	/ea	$3,477.33	
Materials & Services:					
Level D PPE	96	$10.00	/day	$960.00	
Level C PPE	12	$35.00	/day	$420.00	
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Pit Water Disposal	20	$1.62	/kgal	$32.40	
				Subtotal	**$397,591.00**

Table 4-2

Alternative 2 Cost Estimate
TNT Area C
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) = 2103
9. Swell factor for soil upon excavation = 1.3
10. Volume of unconsolidated soil to be treated (cy) = 2734
11. Compost treatment duration (weeks) = 16
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 required windrows (ea) = 9.3
21. Volume of manure (cy) = 317
22. Volume of straw (cy) = 7885
23. Compost additive volume correction factor = 0.8
24. Total volume of compost prior to treatment (cy) = 8,748
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 = 60
    - EnSys TNT 20, no. of samples per kit = 19
    - Total NAC, one per batch. Number of samples = 60
29. Compliance testing shall be performed per windrow and upon compost treatment. Sampling shall consist of:
    - Total Semivolatiles. Number of samples = 10
    - Total NACs. Number of samples = 10
    -TCLP 2,4-DNT. Number of samples = 10
30. Standard work week is 7 days per week at 8 hours per day. Thus, assuming 30 working days per month.

Table 4-2

Alternative 2 Cost Estimate
TNT Area C
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	896	$49.00	/hr	$43,904.00	
QA (Sampling) Coordinator	896	$36.00	/hr	$32,256.00	
H&S Coordinator	896	$49.00	/hr	$43,904.00	
Windrow Turner Operator	112	$567.20	/day	$63,526.40	
Equipment Operator	112	$406.00	/day	$45,472.00	
Equipment Operator	112	$406.00	/day	$45,472.00	
Equipment Operator	112	$406.00	/day	$45,472.00	
Laborer	112	$341.60	/day	$38,259.20	
Environmental Tech	112	$200.00	/day	$22,400.00	
Equipment:					
Windrow Turner (6' x 19')	4	$45,000.00	/mo	$180,000.00	
Dozer	4	$3,500.00	/mo	$14,000.00	
Excavator	4	$4,000.00	/mo	$16,000.00	
Wheel Loader	4	$5,000.00	/mo	$20,000.00	
Tractor	128	$50.00	/hr	$6,400.00	In-use
Tractor	768	$30.00	/hr	$23,040.00	Stand-by
Straw Blower	128	$40.00	/hr	$5,120.00	In-use
Straw Blower	768	$20.00	/hr	$15,360.00	Stand-by
21000 gallon Frac Tank	4	$1,400.00	/mo	$5,600.00	
21000 gallon Frac Tank	4	$1,400.00	/mo	$5,600.00	
Trash/Pump Hose	1	$3,749.00	/ea	$3,749.00	
Office Trailer	4	$800.00	/mo	$3,200.00	
Porta Jon	4	$175.22	/mo	$700.88	
Generator	4	$170.35	/mo	$681.41	
P/U Truck	4	$1,800.00	/mo	$7,200.00	
Spectrophotometer	1	$3,012.00	/ls	$3,012.00	
Materials:					
Repl. Flails for Windrow Turner	6708	$9.50	/ea	$63,726.00	
Straw	7885	$11.25	/cy	$88,701.39	
Manure	317	$25.00	/cy	$7,928.31	
Water	1027	$9.40	/kgal	$9,653.80	
Level C PPE	672	$35.00	/day	$23,520.00	
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)	4	$572.00	/ea	$2,288.00	
- 19 samples per kit					
Total NACs	60	$145.00	/ea	$8,700.00	
Compliance Sampling:					
TCLP Semivolatiles	10	$175.00	/ea	$1,750.00	
Total NACs	10	$145.00	/ea	$1,450.00	
TCLP 2,4-DNT	10	$175.00	/ea	$1,750.00	
				Subtotal	**$902,996.00**

Table 4-2

Alternative 2 Cost Estimate
TNT Area C
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) =	400	
2. Consolidated volume of D030 soil for haz disposal (cy) =	0	
3. Consolidated volume of PCB soil for haz disposal (cy) =	0	
4.Volume of compost, non-haz disposal (cy) =	8748	
5. Bulk density of compost (tons/cy) =	0.368	
6. Weight of treated compost, non-haz waste (ton) =	3219	
7. Consolidated volume of treated soil (cy) =	2310	
8. Unconsolidated volume of treated soil (cy) =	3003	
9. Unconsolidated volume untreated soil (cy) =	8964	
10. Weight of untreated soil (tons) =	9860	
11. Total volume of non-haz waste for disposal (cy) =	17712	
12. Total weight of non-haz waste for disposal (tons) =	13079	
13. Non-haz waste transportation cost ($/hr) =	72	
14. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
15. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
16. Haz waste transportation cost ($/ton) =	35	
17. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
18. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
19. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
20. Haz waste regulatory fees ($/ton) =	10	
21. Number of crew =	3	
22. Load capacity of a 20 ton truck (tons) =	15	
23. Round trip travel time to non-haz waste landfill (hr) =	1	
24. Loads of non-haz waste or trips (hrs)=	872	
25. Output of front-end loader (cy/day) =	550	
26. No. of wheel loaders =	2	
27. Number of field days =	17	
28. No. of truckloads of stormwater for disposal =	4	
29. Volume of stormwater per truckload (gal) =	4000	
30. Volume of stormwater requiring off-site disposal (gal) =	16000	

31. Stormwater shall be analyzed for TCLP semivolatiles prior to transport.
32. At one sample per truckload, number of samples (ea) = 4
33. Excavated soil is staged in 500 ton piles.
34. One 10-point composite sample shall be collected from each 500-ton pile as part of compliance testing.
35. Standard work week is 5 days per week at 8 hours per day.

Table 4-2

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

6.0 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	
Oiler	17	$293.00	/day	$4,981.00	
Materials:					
Level D PPE	51	$10.00	/day	$510.00	
Equipment:					
Wheel Loader	0.8	$5,000.00	/mo	$4,000.00	
Wheel Loader	0.8	$5,000.00	/mo	$4,000.00	
Office Trailer	0.8	$800.00	/mo	$640.00	
Porta Jon	0.8	$175.22	/mo	$140.18	
Generator	0.8	$170.35	/mo	$136.28	
P/U Truck	0.8	$1,800.00	/mo	$1,440.00	
Disposal Costs:					
Transportation (Non-Haz Waste)	872	$72.00	/hr	$62,784.00	truck & driver
Disposal Cost (Non-Haz waste)	13079	$24.50	/ton	$320,442.62	Erie County Landfill
Transportation (Haz Waste)	572	$35.00	/ton	$20,020.00	
Disposal Cost (D008 haz waste)	572	$85.00	/ton	$48,620.00	
Disposal Cost (D030 haz waste)	0	$160.00	/ton	$0.00	
Disposal Cost (PCB haz waste)	0	$85.00	/ton	$0.00	
Stormwater Disposal	17	$0.25	/gal	$4.25	Enviro-Tank Clean
Analytical:					
Compliance Sampling:					
TCLP SVOC/NAC/metals	21	$400.00	/ea	$8,345.48	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$508,792.00**

Table 4-2

Alternative 2 Cost Estimate
TNT Area C
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) =	9205
2. Compaction factor =	1.15
3. Volume of soil required for backfill (cy) =	10586
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 =	20
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) =	25

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

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	200	$49.00	/hr	$9,800.00	
QA Coordinator	200	$36.00	/hr	$7,200.00	
H&S Coordinator	200	$49.00	/hr	$9,800.00	
Equipment Operator	20	$406.00	/day	$8,120.00	
Equipment Operator	20	$406.00	/day	$8,120.00	
Laborer	20	$341.60	/day	$6,832.00	
Reseeding	1	$5,000.00	/area	$5,000.00	
Road Repair	1	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	1	$3,500.00	/mo	$3,500.00	
Wheel Loader	1	$5,000.00	/mo	$5,000.00	
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	10586	$12.00	/cy	$127,029.00	delivered to site
PID rental	1	$974.00	/mo.	$974.00	
CGI rental	1	$380.00	/mo.	$380.00	
Level D PPE	75	$10.00	/day	$750.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$374,836.00**

Table 4-2

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

8.0 Overall Cost	
Total Capital Cost	**$2,215,215.00**
Contingency (30%)	**$664,565.00**
PM Multiplier (7.5%)	**$166,141.00**
Fee/Profit (10%)	**$221,522.00**
Total Cost	**$3,267,000.00**

*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 4-4

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

Alternative 3
Excavation/Off-Site Disposal/Site Restoration Cost Estimate

Site: TNT Area C
Plum Brook Ordnance Works

Date: 10/31/2008

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	2	$10,000.00	/ea	$20,000.00
			Subtotal	**$35,000.00**

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 4-4

Alternative 3 Cost Estimate
TNT Area C
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 4-4

Alternative 3 Cost Estimate
TNT Area C
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 =	9205
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	11967
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	13163
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 =	24
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 =	40
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 =	286
21. Excavation area (ft^2) =	35583
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 =	3
26. Days screening crew in Level C =	2
27. Perimeter of excavation area (ft) =	3415
28. Excavation area (sf) =	35583
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	192	$49.00	/hr	$9,408.00
QA (Sampling) Coordinator	192	$36.00	/hr	$6,912.00
H&S Coordinator	192	$49.00	/hr	$9,408.00
Chemist (home office)	48	$51.00	/hr	$2,448.00
Equipment Operator	24	$406.00	/day	$9,744.00
Equipment Operator	20	$406.00	/day	$8,120.00
Equipment Operator	20	$406.00	/day	$8,120.00
Laborers	44	$341.60	/day	$15,030.40
Truck Drivers	48	$341.60	/day	$16,396.80

Table 4-4

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

4.0 Excavation of Contaminated Soil (continued)

Equipment:					
Excavator	2	$4,000.00	/mo	$8,000.00	
100-ton/hr Screening Plant	4	$1,800.00	/wk	$7,200.00	
Radial Stacking Conveyor	4	$1,222.00	/wk	$4,888.00	
Dozer	1	$3,500.00	/mo	$3,500.00	
Dump Truck	2	$3,890.00	/mo	$7,780.00	
Dump Truck	2	$3,890.00	/mo	$7,780.00	
3000 gal. Water Truck	24	$402.00	/day	$9,648.00	
21,000 gal Frac Tank	8	$1,400.00	/mo	$11,200.00	
150 gpm Pump	2	$2,439.00	/ea.	$4,878.00	
300 gpm Pump	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	
Analytical:					
TCLP Extraction	40	$12.88	/ea	$515.00	
SVOCs (8270C)	326	$300.00	/ea	$97,800.00	
NACs (8330)	326	$197.50	/ea	$64,385.00	
Lead	326	$30.00	/ea	$9,780.00	
PCBs	326	$103.75	/ea	$33,822.50	
NAC field analyses	286	$40.00	/ea	$11,440.00	
Lead field analyses	2	$4,200.00	/mo.	$8,400.00	
Shipping	87	$40.00	/ea	$3,477.33	
Materials & Services:					
Level D PPE	96	$10.00	/day	$960.00	
Level C PPE	12	$35.00	/day	$420.00	
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Pit Water Disposal	20	$1.62	/kgal	$32.40	
				Subtotal	**$397,591.00**

Table 4-4

Alternative 3 Cost Estimate
TNT Area C
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) =	6895	
2. Volume of unconsolidated, non-hazardous soil (cy) =	8964	
3. Tons of non-hazardous soil for disposal =	9860	
4. Consolidated volume of D008 soil for haz disposal (cy) =	207	
5. Consolidated volume of D030 soil for haz disposal (cy) =	2103	
6. Consolidated volume of PCB soil for haz disposal (cy) =	0	
7. Total volume of unconsolidated hazardous soil (cy) =	3003	
8. Non-haz waste transportation cost ($/hr) =	72	
9. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
10. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
11. Haz waste transportation cost ($/ton) =	35	
12. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
13. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
14. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
15. Haz waste regulatory fees ($/ton) =	10	
16. Number of crew =	3	

17. Load capacity of a 20 ton truck is 15 ton/truck.
18. Travel duration to non-haz landfill is 1 hour, round trip. Thus, one load yield 1 hour of transportation.

20. Loads of non-haz waste or trips (hrs)=	657
21. Output of front-end loader (cy/day) =	550
22. Number of field days =	22
23. Standby time for haz waste disposal (approvals) =	6
24. Total number of days in field (incl standby) =	28

23. Four (4) truckloads of stormwater requiring off-site disposal.
24. 4000 gallons of stormwater per truckload.

25. Volume of stormwater requiring off-site disposal (gal) =	16000

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

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

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

Service/Materials	Unit	Unit Cost		Subtotal
Labor:				
Site Superintendent	224	$49.00	/hr	$10,976.00
QA Coordinator	224	$36.00	/hr	$8,064.00
H&S Coordinator	224	$49.00	/hr	$10,976.00
Equipment Operator	28	$406.00	/day	$11,368.00
Equipment Operator	28	$406.00	/day	$11,368.00
Oiler	28	$293.00	/day	$8,204.00
Materials:				
Level D PPE	84	$10.00	/day	$840.00
Equipment:				
Wheel Loader	1.3	$5,000.00	/mo	$6,500.00
Wheel Loader	1.3	$5,000.00	/mo	$6,500.00
Office Trailer	1.3	$800.00	/mo	$1,040.00
Porta Jon	1.3	$175.22	/mo	$227.78
Generator	1.3	$170.35	/mo	$221.46
P/U Truck	1.3	$1,800.00	/mo	$2,340.00

Table 4-4

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

5.0 Off-Site Disposal (continued)					
Disposal Costs:					
Transportation (Non-Haz Waste)	657	$72.00	/hr	$47,328.68	truck & driver
Disposal Cost (Non-Haz waste)	9860	$24.50	/ton	$241,573.48	
Transportation (Haz Waste)	3303	$35.00	/ton	$115,605.28	
Disposal Cost (D008 haz waste)	296	$85.00	/ton	$25,196.81	
Disposal Cost (D030 haz waste)	3007	$160.00	/ton	$481,052.00	
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	26	$400.00	/ea	$10,530.52	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$1,004,612.00**

Table 4-4

Alternative 3 Cost Estimate
TNT Area C
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) =	10072
2. Compaction factor =	1.15
3. Volume of soil required for backfill (cy) =	11582
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 =	22
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) =	27

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

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	216	$49.00	/hr	$10,584.00	
QA Coordinator	216	$36.00	/hr	$7,776.00	
H&S Coordinator	216	$49.00	/hr	$10,584.00	
Equipment Operator	22	$406.00	/day	$8,932.00	
Equipment Operator	22	$406.00	/day	$8,932.00	
Laborer	22	$341.60	/day	$7,515.20	
Reseeding	1	$5,000.00	/area	$5,000.00	
Road Repair	1	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	1	$3,500.00	/mo	$3,500.00	
Wheel Loader	1	$5,000.00	/mo	$5,000.00	
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	11582	$12.00	/cy	$138,989.00	delivered to site
PID rental	1	$974.00	/mo.	$974.00	
CGI rental	1	$380.00	/mo.	$380.00	
Level D PPE	81	$10.00	/day	$810.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$391,307.00**

Table 4-4

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

7.0 Overall Cost	
Total Capital Cost	**$1,941,966.00**
Contingency (30%)	**$582,590.00**
PM Multiplier (7.5%)	**$145,647.00**
Fee/Profit (10%)	**$194,197.00**
Total Cost	**$2,864,000.00**

*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 4-6

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

Alternative 4	**Site:**	TNT Area C
Excavation/Composting/Stabilization/Off-Site Disposal		Plum Brook Ordnance Works
and Site Restoration Cost Estimate	**Date:**	**10/31/2008**

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**

Table 4-6

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

3.0 Site Preparation

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

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 =	9205
2. Swell factor for soil upon excavation =	1.3
3. Cubic yards of unconsolidated soil =	11967
4. Density of unconsolidated soil (tons/cy) =	1.1
5. Mass of unconsolidated soil (tons) =	13163
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 =	24
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 =	40
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 =	286
21. Excavation area (ft^2) =	35583
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 =	3
26. Days screening crew in Level C =	2
27. Perimeter of excavation area (ft) =	3415
28. Excavation area (sf) =	35583
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	192	$49.00	/hr	$9,408.00
QA (Sampling) Coordinator	192	$36.00	/hr	$6,912.00
H&S Coordinator	192	$49.00	/hr	$9,408.00
Chemist (home office)	48	$51.00	/hr	$2,448.00
Equipment Operator	24	$406.00	/day	$9,744.00
Equipment Operator	20	$406.00	/day	$8,120.00
Equipment Operator	20	$406.00	/day	$8,120.00
Laborers	44	$341.60	/day	$15,030.40
Truck Drivers	48	$341.60	/day	$16,396.80

Table 4-6

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

4.0 Excavation of Contaminated Soil (continued)

Equipment:					
Excavator	2	$4,000.00	/mo	$8,000.00	
100-ton/hr Screening Plant	4	$1,800.00	/wk	$7,200.00	
Radial Stacking Conveyor	4	$1,222.00	/wk	$4,888.00	
Dozer	1	$3,500.00	/mo	$3,500.00	
Dump Truck	2	$3,890.00	/mo	$7,780.00	
Dump Truck	2	$3,890.00	/mo	$7,780.00	
3000 gal. Water Truck	24	$402.00	/day	$9,648.00	
21,000 gal Frac Tank	8	$1,400.00	/mo	$11,200.00	
150 gpm Pump	2	$2,439.00	/ea.	$4,878.00	
300 gpm Pump	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	
Analytical:					
TCLP Extraction	40	$12.88	/ea	$515.00	
SVOCs (8270C)	326	$300.00	/ea	$97,800.00	
NACs (8330)	326	$197.50	/ea	$64,385.00	
Lead	326	$30.00	/ea	$9,780.00	
PCBs	326	$103.75	/ea	$33,822.50	
NAC field analyses	286	$40.00	/ea	$11,440.00	
Lead field analyses	2	$4,200.00	/mo.	$8,400.00	
Shipping	87	$40.00	/ea	$3,477.33	
Materials & Services:					
Level D PPE	96	$10.00	/day	$960.00	
Level C PPE	12	$35.00	/day	$420.00	
PID rental	2	$974.00	/mo.	$1,948.00	
CGI rental	2	$380.00	/mo.	$760.00	
Pit Water Disposal	20	$1.62	/kgal	$32.40	
				Subtotal	**$397,591.00**

Table 4-6

Alternative 4 Cost Estimate
TNT Area C
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) =	2103
9. Swell factor for soil upon excavation =	1.3
10. Volume of unconsolidated soil to be treated (cy) =	2734
11. Compost treatment duration (weeks) =	16
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 required windrows (ea) =	9.3
21. Volume of manure (cy) =	317
22. Volume of straw (cy) =	7885
23. Compost additive volume correction factor =	0.8
24. Total volume of compost prior to treatment (cy) =	8,748
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 =	60
- EnSys TNT 20, no. of samples per kit =	19
- Total NAC, one per batch. Number of samples =	60
29. Compliance testing shall be performed per windrow and upon compost treatment. Sampling shall consist of:	
- Total Semivolatiles. Number of samples =	10
- Total NACs. Number of samples =	10
-TCLP 2,4-DNT. Number of samples =	10
30. Standard work week is 7 days per week at 8 hours per day. Thus, assuming 30 working days per month.	

Table 4-6

Alternative 4 Cost Estimate
TNT Area C
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	896	$49.00	/hr	$43,904.00		
QA (Sampling) Coordinator	896	$36.00	/hr	$32,256.00		
H&S Coordinator	896	$49.00	/hr	$43,904.00		
Windrow Turner Operator	112	$567.20	/day	$63,526.40		
Equipment Operator	112	$406.00	/day	$45,472.00		
Equipment Operator	112	$406.00	/day	$45,472.00		
Equipment Operator	112	$406.00	/day	$45,472.00		
Laborer	112	$341.60	/day	$38,259.20		
Environmental Tech	112	$200.00	/day	$22,400.00		
Equipment:						
Windrow Turner (6' x 19')	4	$45,000.00	/mo	$180,000.00		
Dozer	4	$3,500.00	/mo	$14,000.00		
Excavator	4	$4,000.00	/mo	$16,000.00		
Wheel Loader	4	$5,000.00	/mo	$20,000.00		
Tractor	128	$50.00	/hr	$6,400.00	In-use	
Tractor	768	$30.00	/hr	$23,040.00	Stand-by	
Straw Blower	128	$40.00	/hr	$5,120.00	In-use	
Straw Blower	768	$20.00	/hr	$15,360.00	Stand-by	
21000 gallon Frac Tank	4	$1,400.00	/mo	$5,600.00		
21000 gallon Frac Tank	4	$1,400.00	/mo	$5,600.00		
Trash/Pump Hose	1	$3,749.00	/ea	$3,749.00		
Office Trailer	4	$800.00	/mo	$3,200.00		
Porta Jon	4	$175.22	/mo	$700.88		
Generator	4	$170.35	/mo	$681.41		
P/U Truck	4	$1,800.00	/mo	$7,200.00		
Spectrophotometer	1	$3,012.00	/ls	$3,012.00		
Materials:						
Repl. Flails for Windrow Turner	6708	$9.50	/ea	$63,726.00		
Straw	7885	$11.25	/cy	$88,701.39		
Manure	317	$25.00	/cy	$7,928.31		
Water	1027	$9.40	/kgal	$9,653.80		
Level C PPE	672	$35.00	/day	$23,520.00		
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)	4	$572.00	/ea	$2,288.00		
- 19 samples per kit						
Total NACs	60	$145.00	/ea	$8,700.00		
Compliance Sampling:						
TCLP Semivolatiles	10	$175.00	/ea	$1,750.00		
Total NACs	10	$145.00	/ea	$1,450.00		
TCLP 2,4-DNT	10	$175.00	/ea	$1,750.00		
				Subtotal		**$902,996.00**

Table 4-6

Alternative 4 Cost Estimate
TNT Area C
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)= 400
2. Swell factor for soil upon excavation = 1.3
3. Volume of unconsolidated lead-contaminated soil (cy) = 520
3. Density of soil (ton/cy) = 1.1
4. Lead contaminated soil remains in-place for chemical stabilization.
5. An excavator will punch holes in the soil for installation of the Maectite chemical.
6.The Maectite shall be pumped into the holes.
7. The excavator will turn the soil and the chemical for ample mixture.
8. The production rate is 2 hours to mix 400 cy of soil.
9. Time required to stabilize soil (days) = 2
10. The lump sum price for the Maectite chemical and technician is $10,000 per Serverson Environmental.
11. Number of field crew = 1
12. 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	16	$49.00	/hr	$784.00	
QA (Sampling) Coordinator	16	$36.00	/hr	$576.00	
H&S Coordinator	16	$49.00	/hr	$784.00	
Sampling Technician	16	$28.00	/hr	$448.00	
Equipment Operator	2	$406.00	/day	$812.00	
Equipment:					
Excavator	0.1	$4,000.00	/mo	$400.00	
Office Trailer	0.1	$800.00	/mo	$80.00	
Porta Jon	0.1	$175.22	/mo	$17.52	
Generator	0.1	$170.35	/mo	$17.04	
P/U Truck	0.1	$1,800.00	/mo	$180.00	
Materials:					
Maectite Chemical Stabilization	1	$10,000.00	/ls	$10,000.00	(Sevenson tech incl)
Level D PPE	2	$10.00	/day	$20.00	
PID rental	0.1	$974.00	/mo.	$97.40	
CGI rental	0.1	$380.00	/mo.	$38.00	
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	**$14,731.00**

Table 4-6

Alternative 4 Cost Estimate
TNT Area C
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) =	0	
3. Consolidated volume of PCB soil for haz disposal (cy) =	0	
4.Volume of compost, non-haz disposal (cy) =	8748	
5. Bulk density of compost (tons/cy) =	0.368	
6. Weight of treated compost, non-haz waste (ton) =	3219	
7. Volume of unconsolidated stabilized soil (cy) =	520	
8. Density of soil (ton/cy) =	1.1	
9. Weight of treated stabilized soil (tons) =	572	
10. Consolidated volume of treated soil (cy) =	2103	
11. Unconsolidated volume of treated soil (cy) =	2734	
12. Unconsolidated volume untreated soil (cy) =	9233	
13. Weight of untreated soil (tons) =	10156	
14. Total volume of non-haz waste for disposal (cy) =	18501	
15. Total weight of non-haz waste for disposal (tons) =	13947	
16. Non-haz waste transportation cost ($/hr) =	72	
17. Non-haz waste disposal costs ($/ton) =	24.5	Erie County Landfill
18. Non-haz waste regulatory fees ($/ton) =	0	included in disposal
19. Haz waste transportation cost ($/ton) =	35	
20. D008 Haz waste disposal cost ($/ton) =	75	EO Environmental
21. D030 Haz waste disposal cost ($/ton) =	150	EO Environmental
22. PCB Haz waste disposal cost ($/ton) =	75	EO Environmental
23. Haz waste regulatory fees ($/ton) =	10	
24. Number of crew =	3	
25. Load capacity of a 20 ton truck (tons) =	15	
26. Round trip travel time to non-haz waste landfill (hr) =	1	
27. Loads of non-haz waste or trips (hrs)=	930	
28. Output of front-end loader (cy/day) =	550	
29. No. of wheel loaders =	2	
30. Number of field days =	17	
31. No. of truckloads of stormwater for disposal =	4	
32. Volume of stormwater per truckload (gal) =	4000	
33. Volume of stormwater requiring off-site disposal (gal) =	16000	

34. Stormwater shall be analyzed for TCLP semivolatiles prior to transport.
35. At one sample per truckload, number of samples (ea) = 4
36. Excavated soil is staged in 500 ton piles.
37. One 10-point composite sample shall be collected from each 500-ton pile as part of compliance testing.
38. Standard work week is 5 days per week at 8 hours per day.

Table 4-6

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

7.0 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	
Oiler	17	$293.00	/day	$4,981.00	
Materials:					
Level D PPE	51	$10.00	/day	$510.00	
Equipment:					
Wheel Loader	0.8	$5,000.00	/mo	$4,000.00	
Wheel Loader	0.8	$5,000.00	/mo	$4,000.00	
Office Trailer	0.8	$800.00	/mo	$640.00	
Porta Jon	0.8	$175.22	/mo	$140.18	
Generator	0.8	$170.35	/mo	$136.28	
P/U Truck	0.8	$1,800.00	/mo	$1,440.00	
Disposal Costs:					
Transportation (Non-Haz Waste)	930	$72.00	/hr	$66,960.00	truck & driver
Disposal Cost (Non-Haz waste)	13947	$24.50	/ton	$341,708.87	Erie County Landfill
Transportation (Haz Waste)	0	$35.00	/ton	$0.00	
Disposal Cost (D008 haz waste)	0	$85.00	/ton	$0.00	
Disposal Cost (D030 haz waste)	0	$160.00	/ton	$0.00	
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	20	$400.00	/ea	$8,124.69	
Stormwater Sampling:					
TCLP 2,4-DNT	4	$175.00	/ea	$700.00	
				Subtotal	**$469,369.00**

Table 4-6

Alternative 4 Cost Estimate
TNT Area C
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) =	9205
2. Compaction factor =	1.15
3. Volume of soil required for backfill (cy) =	10586
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 =	20
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) =	25

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

Service/Materials	Unit	Unit Cost		Subtotal	
Labor:					
Site Superintendent	200	$49.00	/hr	$9,800.00	
QA Coordinator	200	$36.00	/hr	$7,200.00	
H&S Coordinator	200	$49.00	/hr	$9,800.00	
Equipment Operator	20	$406.00	/day	$8,120.00	
Equipment Operator	20	$406.00	/day	$8,120.00	
Laborer	20	$341.60	/day	$6,832.00	
Reseeding	1	$5,000.00	/area	$5,000.00	
Road Repair	1	$175,000.00	/ls	$175,000.00	Erie Blacktop
Equipment:					
Dozer	1	$3,500.00	/mo	$3,500.00	
Wheel Loader	1	$5,000.00	/mo	$5,000.00	
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	10586	$12.00	/cy	$127,029.00	delivered to site
PID rental	1	$974.00	/mo.	$974.00	
CGI rental	1	$380.00	/mo.	$380.00	
Level D PPE	75	$10.00	/day	$750.00	
Analytical:					
SVOCs	4	$175.00	/ea	$700.00	
NACs (8330)	4	$145.00	/ea	$580.00	
Shipping	4	$40.00	/ea	$160.00	
				Subtotal	**$374,836.00**

Table 4-6

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

9.0 Overall Cost	
Total Capital Cost	**$2,190,523.00**
Contingency (30%)	**$657,157.00**
PM Multiplier (7.5%)	**$164,289.00**
Fee/Profit (10%)	**$219,052.00**
Total Cost	**$3,231,000.00**

*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 5-2

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

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and On-Site/Off-Site Disposal	**Alternative 4:** Excavation and Off-Site Disposal	**Alternative 5:** Excavation, Windrow Composting, Ex-Situ Stabilization, and On-Site/Off-Site Disposal	**Alternative 6:** Excavation, Alkaline Hydrolysis, Ex-Situ Stabilization, 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.

Table 5-2

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

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and On-Site/Off-Site Disposal	**Alternative 4:** Excavation and Off-Site Disposal	**Alternative 5:** Excavation, Windrow Composting, Ex-Situ Stabilization, and On-Site/Off-Site Disposal	**Alternative 6:** Excavation, Alkaline Hydrolysis, Ex-Situ Stabilization, and Off-Site Disposal
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.
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.

Table 5-2

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

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and On-Site/Off-Site Disposal	**Alternative 4:** Excavation and Off-Site Disposal	**Alternative 5:** Excavation, Windrow Composting, Ex-Situ Stabilization, and On-Site/Off-Site Disposal	**Alternative 6:** Excavation, Alkaline Hydrolysis, Ex-Situ Stabilization, and Off-Site Disposal
Amount Destroyed or Treated	None	25% of contaminated soil treated on-site.	No on-site treatment.	25% of contaminated soil treated on-site.	25% of contaminated soil treated on-site.
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. 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.

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TNT Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

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Type and Quantity of Residuals Remaining after Treatment (all volumes are based on in-place, consolidated soil)	Contaminated soil remains.	8,805 cy of treated and untreated soil for offsite disposal as a nonhazardous waste at a solid waste landfill. 400 cy lead-contaminated soil for off-site treatment and disposal at a Subtitle C TSDF.	6,805 cy of untreated soil for offsite disposal as a nonhazardous waste at a solid waste landfill. 2,310 cy 2,4-DNT and lead-contaminated soil for off-site treatment and disposal at a Subtitle C TSDF.	9,205 cy of treated and untreated soil for offsite disposal as a non-hazardous waste at a solid waste landfill.	7,295 cy of treated and untreated soil for offsite disposal as a non-hazardous waste at a solid waste landfill.
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.

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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.

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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	16 to 22 months	10 to 16 months	16 to 22 months	16 to 22 months

Table 5-2

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

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Implementability					
Ability to Construct and Operate	No construction or operation.	Technology well developed and implemented on a full-scale basis at numerous sites.	No significant issues.	Technologies well developed and implemented on a full-scale basis at numerous sites.	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.
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 5-2

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

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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 available locally.

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

Criteria	**Alternative 1:** No Action	**Alternative 2:** Excavation, Windrow Composting, and On-Site/Off-Site Disposal	**Alternative 4:** Excavation and Off-Site Disposal	**Alternative 5:** Excavation, Windrow Composting, Ex-Situ Stabilization, and On-Site/Off-Site Disposal	**Alternative 6:** Excavation, Alkaline Hydrolysis, Ex-Situ Stabilization, and Off-Site Disposal
Availability of Technologies	None required	Available	Available	Available	Available
Cost					
Capital Cost	None	$3.3 million	$2.9 million	$3.2 million	$2.4 million
Annual O&M Cost	None	None	None	None	None
Present Worth Cost	None	$3.3 million	$2.9 million	$3.2 million	$2.4 million
State Acceptance	Not acceptable	To be determined	To be determined	To be determined	To be determined
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

Figure 3-1

Cometabolic Reduction of
2,4,6-TNT During Fermentation of Glucose
Former Plum Brook Ordnance Works, Sandusky, Ohio

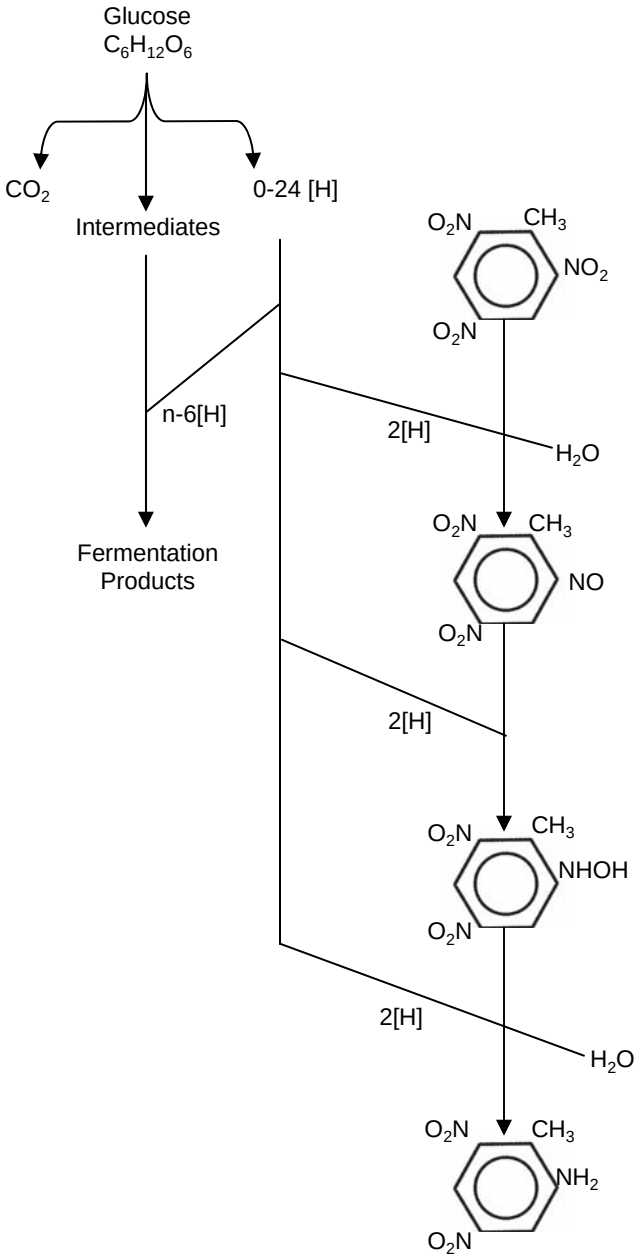


Figure 3-2
Transformation and Humification of TNT in an Anaerobic/ Aerobic Composting System

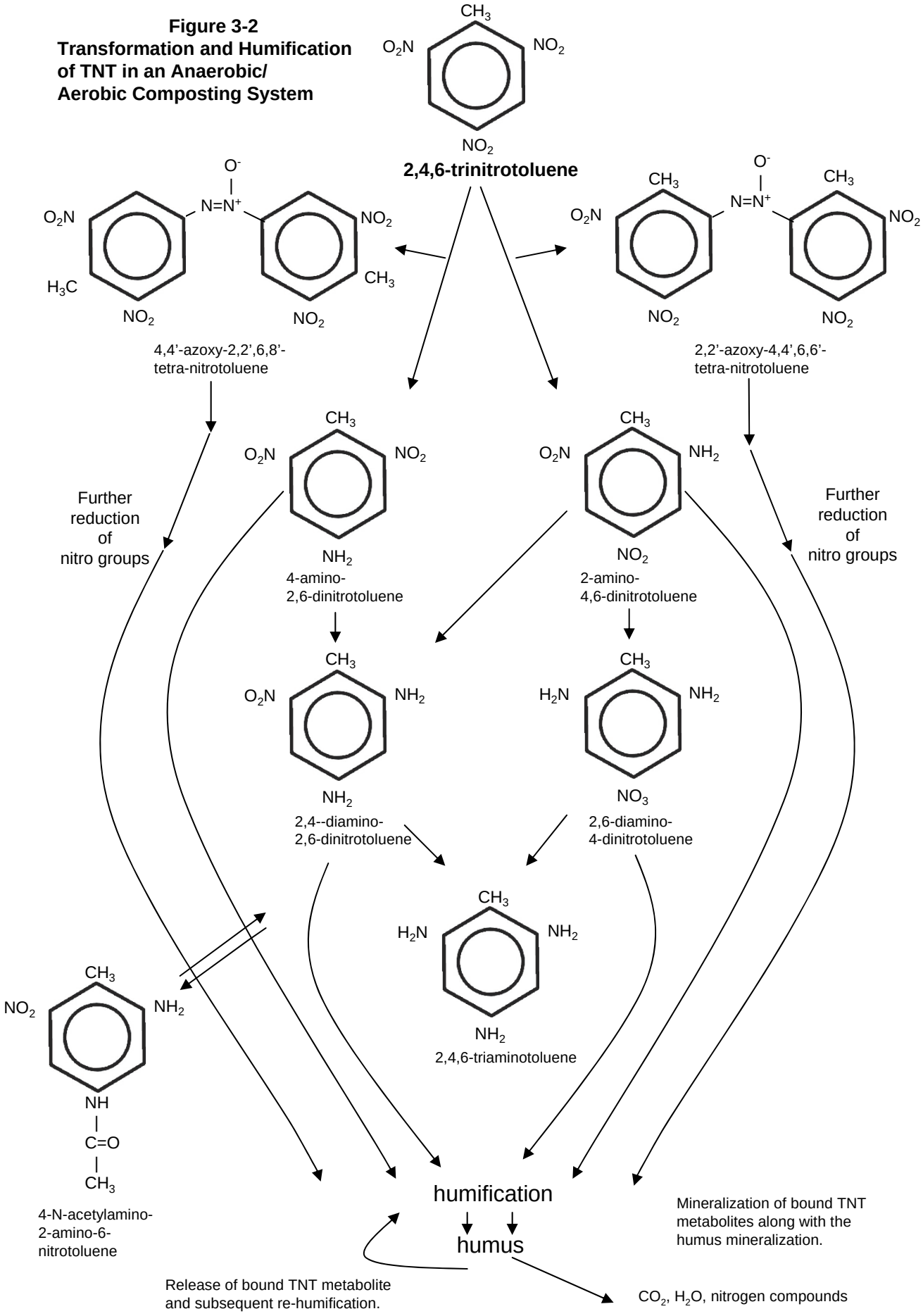
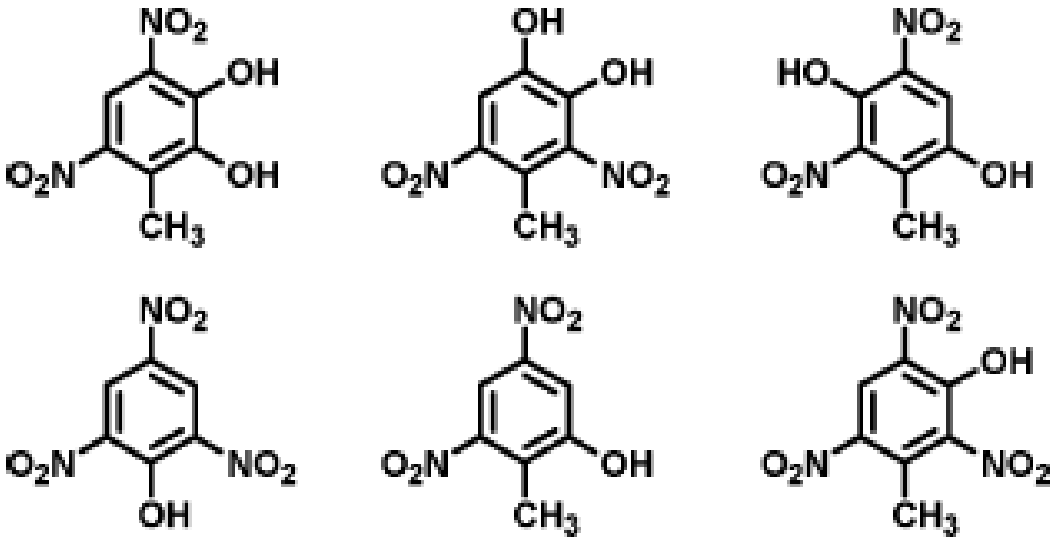


Figure 3-3

Structures from the Initial Attack of Hydroxide Ion on Trinitrotoluene

TNT Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

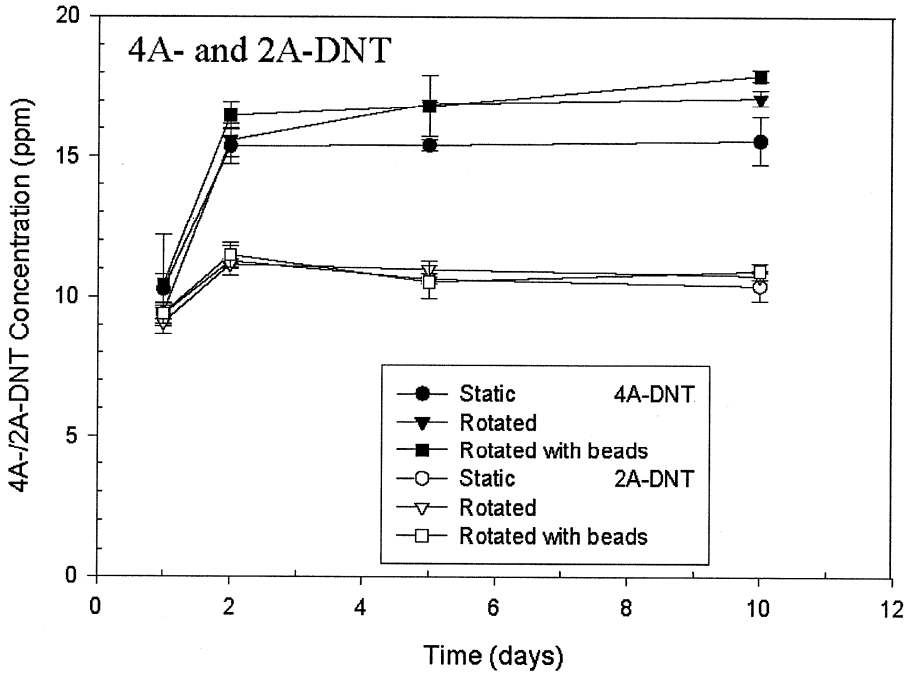


Reference: Thorn, K., P. Thorne, L. Cox, 2004, "Alkaline Hydrolysis/Polymerization of 2,4,6-Trinitrotoluene: Characterization of Products by 13C and 15N NMR," ***Environmental Science and Technology***, 38(7), 2224-2231.

Figure 3-4

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

TNT Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio



(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.