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Prepared by: Strategic Services Division
Phone Number: (314) 539-1600 (U.S.A.)

Please reduce your browser font size for better viewing and printing.

MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

J.T.Baker

24 Hour Emergency Telephone: [illegible]
CHEMTREC: 1-800-424-[illegible]

National Response in Canada
CANUTEC: 613-[illegible]

Outside U.S. and Canada
Chemtrec: 202-483-7616

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

ARSENIC, 1000 ug/ml (0.10% w/v)

MSDS Number: A7440 — ***Effective Date: 11/06/97***

1. Product Identification

Synonyms: None
CAS No.: 7647-01-0
Molecular Weight: 36.46
Chemical Formula: mostly water
Product Codes: 6919

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Arsenic Trioxide	1327-53-3	< 1%	Yes
Hydrogen Chloride	7647-01-0	1 - 2%	Yes
Water	7732-18-5	> 97%	No

3. Hazards Identification

Emergency Overview

DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. CANCER HAZARD. CONTAINS INORGANIC ARSENIC WHICH CAN CAUSE CANCER. Risk of cancer depends on duration and level of exposure. MAY CAUSE LIVER AND KIDNEY DAMAGE.

J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 4 - Extreme (Cancer Causing)
Flammability Rating: 0 - None
Reactivity Rating: 2 - Moderate

Contact Rating: 2 - Moderate
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Health hazards given on this data sheet apply to concentrated (5 - 37%) solutions of hydrochloric acid. Hazards of this product are expected to be reduced. Degree of hazard for these reduced concentrations is not currently addressed in the available literature.

Inhalation:
Symptoms are expected to be less severe than exposure to higher concentrations of hydrochloric acid, where symptoms may include irritation to the respiratory tract.
Ingestion:
Symptoms are expected to be less severe than exposure to higher concentrations of hydrochloric acid, where symptoms may include burning sensation, vomiting and diarrhea. Arsenic is highly toxic! May cause burning in esophagus, vomiting, and bloody diarrhea. Symptoms of cold and clammy skin, low blood pressure, weakness, headache, cramps, convulsions, and coma may follow. May cause damage to liver and kidneys. A suspected fetal toxin. Death may occur from circulatory failure. Estimated lethal dose 120 milligrams.
Skin Contact:
Symptoms are expected to be less severe than exposure to higher concentrations of hydrochloric acid, where symptoms may include irritation, redness, pain and burns.
Eye Contact:
Splashes cause irritation. Symptoms are expected to be less severe than exposure to higher concentrations of hydrochloric acid, where symptoms may include severe burns and eye damage.
Chronic Exposure:
Arsenic on repeated or prolonged skin contact may cause bronzing of the skin, edema, dermatitis, and lesions. Repeated or prolonged inhalation of dust may cause damage to the nasal septum. Chronic exposure from inhalation or ingestion may cause hair and weight loss, a garlic odor to the breath and perspiration, excessive salivation and perspiration, central nervous system damage, hepatitis, gastrointestinal disturbances, cardiovascular damage, and kidney and liver damage. Arsenic compounds are known human carcinogens and may be teratogenic based on effects in laboratory animals.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye disease, or cardiopulmonary diseases may be more susceptible to the effects of this substance.

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4. First Aid Measures

First aid procedures given apply to concentrated solutions. Exposures to dilute solutions may not require these extensive first aid procedures.
Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.
Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:

Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention immediately. Wash clothing before reuse. Thoroughly clean shoes before reuse. Contaminated work clothes should be laundered by individuals who have been informed of the hazards of exposure to this substance.

Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

Note to Physician:
If emesis if unsuccessful after two doses of Ipecac, consider gastric lavage. Monitor urine arsenic level. Alkalization of urine may help prevent disposition of red cell breakdown products in renal tubular cells. If acute exposure is significant, maintain high urine output and monitor volume status, preferably with central venous pressure line. Abdominal X-rays should be done routinely for all ingestions. Chelation therapy with BAL, followed by n-penicillamine is recommended, but specific dosing guidelines are not clearly established.

5. Fire Fighting Measures

Fire:
Not considered to be a fire hazard. May react with metals or heat to release flammable hydrogen gas.

Explosion:
Not considered to be an explosion hazard.

Fire Extinguishing Media:
Water or water spray. Neutralize with soda ash or slaked lime.

Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Structural firefighter's protective clothing is ineffective for fires involving hydrochloric acid. Stay away from ends of tanks. Cool tanks with water spray until well after fire is out.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Neutralize with alkaline material (soda ash, lime), then absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker NEUTRASORB(tm) or TEAM(tm) 'Low Na+' acid neutralizers are recommended for spills of this product.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Protect from freezing. Isolate from incompatible substances. Wear special protective equipment (Sec. 8) for maintenance break-in or where exposures may exceed established exposure levels. Wash hands, face, forearms and neck when exiting restricted areas. Shower, dispose of outer clothing, change to clean garments at the end of the day. Avoid cross-contamination of street clothes. Wash hands before eating and do not eat, drink, or smoke in workplace. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
For Hydrochloric acid:
- OSHA Permissible Exposure Limit (PEL):
5 ppm (Ceiling)
- ACGIH Threshold Limit Value (TLV):
5 ppm (STEL/Ceiling)

For Inorganic Arsenic compounds (as As):
- OSHA Permissible Exposure Limit (PEL):
10 (u)g/m3 (TWA), 5 (u)g/m3(Action Level), cancer hazard.
- ACGIH Threshold Limit Value (TLV):
0.01 mg/m3 (TWA), A1, confirmed human carcinogen.

Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices* , most recent edition, for details.

Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, a half-face respirator with an acid gas cartridge may be worn for up to ten times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. A full-face piece respirator with an acid gas cartridge may be worn up to 50 times the exposure limit, or the maximum use concentration specified by the appropriate regulatory agency, or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.

Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

Other Control Measures:
Any area where inorganic arsenic is stored, handled, used, etc., must be established as a 'Regulated Area' with controlled access, limited to authorized persons. Containers of inorganic arsenic and Regulated Areas must be labeled to show a CANCER SUSPECT AGENT is present. Eating, drinking, and smoking should not be permitted in areas where solids or liquids containing arsenic or lead compounds are handled, processed, or stored.

See OSHA substance-specific standard for more information on personal protective equipment, engineering and work practice controls, medical surveillance, record keeping, and reporting requirements. (arsenic: 29 CFR 1910 .1018; lead: 29 CFR 1910.1025).

9. Physical and Chemical Properties

Appearance:
Clear, colorless solution.
Odor:
Odorless.
Solubility:
Infinitely soluble.
Specific Gravity:
ca. 1
pH:
No information found.
% Volatiles by volume @ 21C (70F):
> 99
Boiling Point:
ca. 100C (ca. 212F)
Melting Point:
ca. 0C (ca. 32F)
Vapor Density (Air=1):
Essentially the same as water. Not applicable.
Vapor Pressure (mm Hg):
Essentially the same as water.
Evaporation Rate (BuAc=1):
Essentially the same as water.

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage.
Hazardous Decomposition Products:
When heated to decomposition, emits toxic hydrogen chloride fumes and will react with water or steam to produce heat and toxic and corrosive fumes. Thermal oxidative decomposition produces toxic chlorine fumes and explosive hydrogen gas. Emits toxic fumes of arsenic when heated to decomposition.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
A strong mineral acid, concentrated hydrochloric acid is highly reactive with strong bases, metals, metal oxides, hydroxides, amines, carbonates and other alkaline materials. Incompatible with materials such as cyanides, sulfides, sulfites, and formaldehyde.
Conditions to Avoid:
Heat, direct sunlight, incompatibles.

11. Toxicological Information

Toxicological Data:

Hydrochloric acid: Inhalation rat LC50: 3124 ppm/1H; Oral rabbit LD50: 900 mg/kg. Investigated as a tumorigen, mutagen, reproductive effector. Arsenic trioxide: oral rat LD50: 14.6 mg/kg; investigated as a mutagen, tumorigen, reproductive effector.
Carcinogenicity:
For arsenic and inorganic arsenic compounds:
Regulated by OSHA as a carcinogen.
EPA / IRIS classification: Group A - Known human carcinogen.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Arsenic Trioxide (1327-53-3)	Yes	No	1
Hydrogen Chloride (7647-01-0)	No	No	3
Water (7732-18-5)	No	No	None

12. Ecological Information

Environmental Fate:
For Hydrochloric Acid (Concentrated Solutions):
When released into the soil, this material is not expected to biodegrade. When released into the soil, this material may leach into groundwater.
Environmental Toxicity:
For Hydrochloric Acid (Concentrated Solutions):
This material may be toxic to aquatic life. LC50 Shrimp: 100-300 ppm/48-hr/salt water; LC100 trout: 10 mg/l/24-hr; TLm mosquito fish: 282 ppm/96-hr.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (HYDROGEN CHLORIDE)
Hazard Class: 8
UN/NA: UN3264
Packing Group: III
Information reported for product/size: 500ML

International (Water, I.M.O.)

Proper Shipping Name: CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (HYDROGEN CHLORIDE)
Hazard Class: 8

UN/NA: UN3264
Packing Group: III
Information reported for product/size: 500ML

International (Air, I.C.A.O.)

Proper Shipping Name: CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (HYDROGEN CHLORIDE)
Hazard Class: 8
UN/NA: UN3264
Packing Group: III
Information reported for product/size: 500ML

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\--------

Ingredient	TSCA	EC	Japan	Australia
Arsenic Trioxide (1327-53-3)	Yes	Yes	Yes	Yes
Hydrogen Chloride (7647-01-0)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Arsenic Trioxide (1327-53-3)	Yes	Yes	No	Yes
Hydrogen Chloride (7647-01-0)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\--------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Arsenic Trioxide (1327-53-3)	1	100*	No	Arsenic comp
Hydrogen Chloride (7647-01-0)	5000	500*	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\--------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Arsenic Trioxide (1327-53-3)	1	P012	No
Hydrogen Chloride (7647-01-0)	5000	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: No (Mixture / Liquid)

WARNING:
THIS PRODUCT CONTAINS CHEMICALS KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM.

Australian Hazchem Code: No information found.
Poison Schedule: S6
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products

Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: **2** Flammability: **0** Reactivity: **0**
Label Hazard Warning:
DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. CANCER HAZARD. CONTAINS INORGANIC ARSENIC WHICH CAN CAUSE CANCER. Risk of cancer depends on duration and level of exposure. MAY CAUSE LIVER AND KIDNEY DAMAGE.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe mist.
Keep container closed.
Use only with adequate ventilation.
Wash thoroughly after handling.
Label First Aid:
In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. In all cases get medical attention immediately.
Product Use:
Laboratory Reagent.
Revision Information:

Disclaimer:
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Prepared by: Strategic Services Division
Phone Number: (314) 539-1600 (U.S.A.)

Please reduce your browser font size for better viewing and printing.

MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

24 Hour Emergency Telephone: [illegible]
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 202-483-7616

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

BARIUM, 1,000 UG/ML OR 10,000 UG/ML

MSDS Number: B0334 — ***Effective Date: 02/12/98***

1. Product Identification

Synonyms: None
CAS No.: Not applicable to mixtures.
Molecular Weight: 137.33
Chemical Formula: Ba
Product Codes: 5705, 5719

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Barium Nitrate	10022-31-8	< 2%	Yes
Nitric Acid	7697-37-2	< 4%	Yes
Water	7732-18-5	> 94%	No

3. Hazards Identification

Emergency Overview

DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. VAPOR IRRITATING TO EYES AND RESPIRATORY TRACT. INHALATION MAY CAUSE LUNG AND TOOTH DAMAGE.

J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 3 - Severe (Life)
Flammability Rating: 0 - None
Reactivity Rating: 1 - Slight
Contact Rating: 3 - Severe (Corrosive)

Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Nitric acid is extremely hazardous; it is corrosive, reactive, an oxidizer, and a poison. The health effects from exposure to diluted forms of this chemical are not well documented. They are expected to be less severe than those for concentrated forms which are referenced in the descriptions below.

Inhalation:
Corrosive! Inhalation of vapors can cause breathing difficulties and lead to pneumonia and pulmonary edema, which may be fatal. Other symptoms may include coughing, choking, and irritation of the nose, throat, and respiratory tract.
Ingestion:
Corrosive! Swallowing nitric acid can cause immediate pain and burns of the mouth, throat, esophagus and gastrointestinal tract.
Skin Contact:
Corrosive! Can cause redness, pain, and severe skin burns. Concentrated solutions cause deep ulcers and stain skin a yellow or yellow-brown color.
Eye Contact:
Corrosive! Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Chronic Exposure:
Long-term exposure to concentrated vapors may cause erosion of teeth and lung damage. Long-term exposures seldom occur due to the corrosive properties of the acid.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye disease, or cardiopulmonary diseases may be more susceptible to the effects of this substance.

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4. First Aid Measures

Immediate first aid treatment reduces the health effects of this substance.
Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.
Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention immediately. Wash clothing before reuse. Thoroughly clean shoes before reuse.
Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

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5. Fire Fighting Measures

Fire:
Not combustible, but concentrated material is a strong oxidizer and its heat of reaction with reducing agents or combustibles may cause ignition.
Explosion:
Concentrated material reacts explosively with combustible organic or readily oxidizable materials such as: alcohols, turpentine, charcoal, organic refuse, metal powder, hydrogen sulfide, etc. Reacts with most metals to release hydrogen gas which can form explosive mixtures with air.
Fire Extinguishing Media:
If involved in a fire, use water spray.
Special Information:
Increases the flammability of combustible, organic and readily oxidizable materials. In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Neutralize with alkaline material (soda ash, lime), then absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker NEUTRASORB(tm) or TEAM(tm) 'Low Na+' acid neutralizers are recommended for spills of this product.

7. Handling and Storage

Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Protect from physical damage. Keep out of direct sunlight and away from heat, water, and incompatible materials. Do not wash out container and use it for other purposes. When diluting, the acid should always be added slowly to water and in small amounts. Never use hot water and never add water to the acid. Water added to acid can cause uncontrolled boiling and splashing. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
For Nitric Acid:
OSHA Permissible Exposure Limit (PEL):
2 ppm (TWA)
ACGIH Threshold Limit Value (TLV):
2 ppm (TWA); 4 ppm (STEL)

For Soluble Barium Compounds:
OSHA Permissible Exposure Limit (PEL):
0.5 mg (Ba)/m3
ACGIH Threshold Limit Value (TLV):
0.5 mg (Ba)/m3

Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices* , most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, wear a supplied air, full-facepiece respirator, airlined hood, or full-facepiece self-contained breathing apparatus. Canister-type respirators using sorbents are ineffective.
Skin Protection:
Rubber or neoprene gloves and additional protection including impervious boots, apron, or coveralls, as needed in areas of unusual exposure to prevent skin contact.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

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9. Physical and Chemical Properties

Appearance:
Clear, colorless liquid.
Odor:
Odorless.
Solubility:
Infinitely soluble.
Specific Gravity:
No information found.
pH:
No information found.
% Volatiles by volume @ 21C (70F):
> 99
Boiling Point:
No information found.
Melting Point:
No information found.
Vapor Density (Air=1):
Not applicable.
Vapor Pressure (mm Hg):
Not applicable.
Evaporation Rate (BuAc=1):
No information found.

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10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage. Containers may burst when heated.
Hazardous Decomposition Products:
When heated to decomposition, emits toxic nitrogen oxides fumes and hydrogen nitrate.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
A dangerously powerful oxidizing agent, concentrated nitric acid is incompatible with most substances, especially strong bases, metallic powders, carbides, hydrogen sulfide, turpentine, and combustible organics.
Conditions to Avoid:
Heat, incompatibles.

11. Toxicological Information

For Nitric Acid: Investigated as a mutagen and reproductive effector. For Barium Nitrate: Oral rat LD50: 355 mg/kg. Irritation Data: Skin rabbit 500 mg/24H mild. Eye rabbit 100 mg/24H severe.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Barium Nitrate (10022-31-8)	No	No	None
Nitric Acid (7697-37-2)	No	No	None
Water (7732-18-5)	No	No	None

12. Ecological Information

Environmental Fate:
No information found.
Environmental Toxicity:
No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S.

(NITRIC ACID)
Hazard Class: 8
UN/NA: UN3264
Packing Group: III
Information reported for product/size: 100ML

International (Water, I.M.O.)

Proper Shipping Name: CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (NITRIC ACID)
Hazard Class: 8
UN/NA: UN3264
Packing Group: III
Information reported for product/size: 100ML

International (Air, I.C.A.O.)

Proper Shipping Name: CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (NITRIC ACID)
Hazard Class: 8
UN/NA: UN3264
Packing Group: III
Information reported for product/size: 100ML

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\--------

Ingredient	TSCA	EC	Japan	Australia
Barium Nitrate (10022-31-8)	Yes	Yes	Yes	Yes
Nitric Acid (7697-37-2)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Barium Nitrate (10022-31-8)	Yes	Yes	No	Yes
Nitric Acid (7697-37-2)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\--------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Barium Nitrate (10022-31-8)	No	No	No	Barium compo
Nitric Acid (7697-37-2)	1000	1000	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\--------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Barium Nitrate (10022-31-8)	No	No	No
Nitric Acid (7697-37-2)	1000	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No

Reactivity: No (Mixture / Liquid)

Australian Hazchem Code: No information found.
Poison Schedule: S6
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

---

16. Other Information

NFPA Ratings: Health: 3 Flammability: **0** Reactivity: **0**
Label Hazard Warning:
DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. VAPOR IRRITATING TO EYES AND RESPIRATORY TRACT. INHALATION MAY CAUSE LUNG AND TOOTH DAMAGE.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor or mist.
Use only with adequate ventilation.
Wash thoroughly after handling.
Keep container closed.
Label First Aid:
In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In all cases get medical attention immediately.
Product Use:
Industrial chemical.
Revision Information:
MSDS Section(s) changed since last revision of document include: 3, 5, 7, 8, 10, 13, 16.
Disclaimer:
****

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Please reduce your browser font size for better viewing and printing.

MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

J.T.Baker

24 Hour Emergency Telephone: [illegible]
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 202-483-7616

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

Copper, 1000 (u)g/mL (0.10% w/v)

MSDS Number: C5166 — *Effective Date: 09/08/97*

1. Product Identification

Synonyms: None
CAS No.: Not applicable to mixtures.
Molecular Weight: Not applicable to mixtures.
Chemical Formula: Cu and HNO3 in H2O
Product Codes: 6928

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Copper	7440-50-8	< 1%	No
Nitric Acid	7697-37-2	1 - 2%	Yes
Water	7732-18-5	97 - 98%	No

3. Hazards Identification

Emergency Overview

DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. VAPOR IRRITATING TO EYES AND RESPIRATORY TRACT. INHALATION MAY CAUSE LUNG AND TOOTH DAMAGE.

J.T. Baker SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 2 - Moderate
Flammability Rating: 0 - None
Reactivity Rating: 1 - Slight
Contact Rating: 3 - Severe (Corrosive)

Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Nitric acid is extremely hazardous; it is corrosive, reactive, an oxidizer, and a poison. The following hazards are for concentrated solutions. Hazards of less concentrated solutions may be reduced. Degree of hazard for reduced concentrations is not currently addressed in the available literature.

Inhalation:
Corrosive! Inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory failure, and death.
Ingestion:
Corrosive! Swallowing can cause immediate pain and burns of the mouth, throat, esophagus and gastrointestinal tract. May cause nausea, vomiting, and diarrhea, and in severe cases, death.
Skin Contact:
Corrosive! Can cause redness, pain, and severe skin burns. Concentrated solutions cause deep ulcers and stain skin a yellow or yellow-brown color.
Eye Contact:
Corrosive! Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Chronic Exposure:
Long-term exposure to concentrated vapors may cause erosion of teeth and lung damage. Long-term exposures seldom occur due to the corrosive properties of the acid.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye disease, or cardiopulmonary diseases may be more susceptible to the effects of this substance.

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4. First Aid Measures

Immediate first aid treatment reduces the health effects of this substance.
Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.
Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention immediately. Wash clothing before reuse. Thoroughly clean shoes before reuse.
Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

---

5. Fire Fighting Measures

Fire:
Nitric Acid Component:
Not combustible, but concentrated material is a strong oxidizer and its heat of reaction with reducing agents or combustibles may cause ignition.
Explosion:
Nitric Acid Component: Concentrated material reacts explosively with combustible organic or readily oxidizable materials such as: alcohols, turpentine, charcoal, organic refuse, metal powder, hydrogen sulfide, etc. Reacts with most metals to release hydrogen gas which can form explosive mixtures with air.
Fire Extinguishing Media:
Use any means suitable for extinguishing surrounding fire.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode.

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6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Neutralize with alkaline material (soda ash, lime), then absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker NEUTRASORB(tm) acid neutralizer is recommended for spills of this product.

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7. Handling and Storage

Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Protect from physical damage. Keep out of direct sunlight and away from heat, water, and incompatible materials. Do not wash out container and use it for other purposes. When diluting, the acid should always be added slowly to water and in small amounts. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

---

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
For Nitric Acid:
OSHA Permissible Exposure Limit (PEL):
2 ppm (TWA)
ACGIH Threshold Limit Value (TLV):
2 ppm (TWA); 4 ppm (STEL)
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures

below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices* , most recent edition, for details.

Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, wear a supplied air, full-facepiece respirator, airlined hood, or full-facepiece self-contained breathing apparatus. Canister-type respirators using sorbents are ineffective.

Skin Protection:
Rubber or neoprene gloves and additional protection including impervious boots, apron, or coveralls, as needed in areas of unusual exposure to prevent skin contact.

Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

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9. Physical and Chemical Properties

Appearance:
Clear, blue liquid.

Odor:
Odorless.

Solubility:
Completely soluble in water.

Specific Gravity:
No information found.

pH:
1.0 (0.1M HNO3)

% Volatiles by volume @ 21C (70F):
ca. 99

Boiling Point:
ca. 100C (ca. 212F)

Melting Point:
ca. 0C (ca. 32F)

Vapor Density (Air=1):
Essentially the same as water.

Vapor Pressure (mm Hg):
Essentially the same as water.

Evaporation Rate (BuAc=1):
Essentially the same as water.

---

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage.

Hazardous Decomposition Products:
When heated to decomposition, emits toxic nitrogen oxides fumes, hydrogen nitrate and copper fumes.

Hazardous Polymerization:
Will not occur.

Incompatibilities:
A dangerously powerful oxidizing agent, concentrated nitric acid is incompatible with

most substances, especially strong bases, metallic powders, carbides, hydrogen sulfide, turpentine, and combustible organics.
Conditions to Avoid:
Heat and incompatibles.

11. Toxicological Information

For Nitric Acid: Investigated as a mutagen and reproductive effector.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Copper (7440-50-8)	No	No	None
Nitric Acid (7697-37-2)	No	No	None
Water (7732-18-5)	No	No	None

12. Ecological Information

Environmental Fate:
No information found.
Environmental Toxicity:
No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\----------

Ingredient	TSCA	EC	Japan	Australia
Copper (7440-50-8)	Yes	Yes	No	Yes
Nitric Acid (7697-37-2)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\----------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Copper (7440-50-8)	Yes	Yes	No	Yes
Nitric Acid (7697-37-2)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Copper (7440-50-8)	No	No	Yes	No
Nitric Acid (7697-37-2)	1000	1000	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Copper (7440-50-8)	5000	No	No
Nitric Acid (7697-37-2)	1000	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: No (Mixture / Liquid)

Australian Hazchem Code: No information found.
Poison Schedule: S5
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

---

16. Other Information

NFPA Ratings: Health: **3** Flammability: **0** Reactivity: **0**
Label Hazard Warning:
DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. VAPOR IRRITATING TO EYES AND RESPIRATORY TRACT. INHALATION MAY CAUSE LUNG AND TOOTH DAMAGE.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor or mist.
Use only with adequate ventilation.
Wash thoroughly after handling.
Keep container closed.
Label First Aid:
In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. In all cases get medical attention immediately.
Product Use:
Laboratory Reagent.

Revision Information:

Disclaimer:
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Prepared by: Strategic Services Division
Phone Number: (314) 539-1600 (U.S.A.)

GAF CHEMICALS -- MICROPOWDER IRON GRADE S-SERIES - METALLIC IRON
MATERIAL SAFETY DATA SHEET
NSN: 681000F024648
Manufacturer's CAGE: 46575
Part No. Indicator: A
Part Number/Trade Name: MICROPOWDER IRON GRADE S-SERIES

General Information

Item Name: METALLIC IRON
Company's Name: GAF CHEMICALS CORPORATION
Company's Street: 1361 ALPS ROAD
Company's City: WAYNE
Company's State: NJ
Company's Country: US
Company's Zip Code: 07470
Company's Emerg Ph #: (800) 228-5635 EXT. 016
Company's Info Ph #: (201) 628-3000
Record No. For Safety Entry: 001
Tot Safety Entries This Stk#: 001
Status: SE
Date MSDS Prepared: 01MAY91
Safety Data Review Date: 24SEP92
Preparer's Company: GAF CHEMICALS CORPORATION
Preparer's St Or P. O. Box: 1361 ALPS ROAD
Preparer's City: WAYNE
Preparer's State: NJ
Preparer's Zip Code: 07470
MSDS Serial Number: BNYCM

Ingredients/Identity Information

Proprietary: NO
Ingredient: IRON
Ingredient Sequence Number: 01
NIOSH (RTECS) Number: NO4565500
CAS Number: 7439-89-6

Physical/Chemical Characteristics

Appearance And Odor: UNIFORM POWDER, 3-6 MICRONS DIAMETER
Boiling Point: 4982F
Melting Point: 2795F
Solubility In Water: INSOLUBLE

Fire and Explosion Hazard Data

Extinguishing Media: CO2
Unusual Fire And Expl Hazrds: STRONG HEAT/SPARKS WILL INITIATE RAPID OXIDATION. W/SUFFICIENT AIR, WILL SPONTANEOUSLY GLOW DULL RED & IGNITE COMBUSTIBLES. DUSTING IN AIR IS EXPLOSION HAZARD.

Reactivity Data

Stability: YES
Cond To Avoid (Stability): HEAT, SPARKS, FLAME, MOISTURE
Materials To Avoid: ACIDS, STRONG OXIDIZING AGENTS, CHLORINE TRIFLUORIDE, FLUORINE, NITROGEN DIOXIDE, IRON
Hazardous Poly Occur: NO

Health Hazard Data

LD50-LC50 Mixture: ORAL (RAT) LD50: 30,000 MG/KG
Route Of Entry - Inhalation: NO
Route Of Entry - Skin: YES
Route Of Entry - Ingestion: NO
Health Haz Acute And Chronic: EYES: RUST RINGS IN CORNEA, IRRITATION,

HYPEREMIA OF CONJUNCTIVA & INFLAMMATION. SKIN: IRRITATION & DERMATITIS.
Carcinogenicity - NTP: NO
Carcinogenicity - IARC: NO
Carcinogenicity - OSHA: NO
Explanation Carcinogenicity: NONE
Signs/Symptoms Of Overexp: EYES: RUST RINGS IN CORNEA, IRRITATION, HYPEREMIA OF CONJUNCTIVA & INFLAMMATION. SKIN: IRRITATION & DERMATITIS.
Emergency/First Aid Proc: EYES: FLUSH W/PLENTY OF WATER. SKIN: WASH AFTER EXPOSURE. INGESTION: INDUCE VOMITING BY DRINKING TWO GLASSES OR WATER & STICKING FINGER DOWN THROAT. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. OBTAIN MEDICAL ATTENTION IN ALL CASES.

Precautions for Safe Handling and Use

Steps If Matl Released/Spill: SCOOP UP. FLUSH SPILL AREA W/WATER.
Waste Disposal Method: DISPOSE OF W/SOLID WASTE ACCORDING TO FEDERAL, STATE & LOCAL REGULATIONS.
Precautions-Handling/Storing: USE W/ADEQUATE VENTILATION.
Other Precautions: MAINTENANCE: WASH EQUIPMENT THOROUGHLY W/STEAM OR WARM WATER. CHECK FOR FLAMMABLES W/EXPLOSION METER & OXYGEN LEVEL W/OXYGEN METER. FOLLOW GOOD SAFETY PRACTICES BEFORE ENTERING EQUIPMENT.

Control Measures

Respiratory Protection: DUST MASK WHERE DUSTING CANNOT BE AVOIDED.
Ventilation: ADEQUATE
Eye Protection: SAFETY GLASSES

Transportation Data

Disposal Data

Label Data

Label Required: YES
Technical Review Date: 24SEP92
Label Date: 10AUG92
Label Status: F
Common Name: MICROPOWDER IRON GRADE S-SERIES
Chronic Hazard: YES
Signal Word: WARNING!
Acute Health Hazard-Slight: X
Contact Hazard-Moderate: X
Fire Hazard-None: X
Reactivity Hazard-Slight: X
Special Hazard Precautions: EYES: RUST RINGS IN CORNEA, IRRITATION, HYPEREMIA OF CONJUNCTIVA & INFLAMMATION. SKIN: IRRITATION & DERMATITIS.
Protect Eye: Y
Protect Respiratory: Y
Label Name: GAF CHEMICALS CORPORATION
Label Street: 1361 ALPS ROAD
Label City: WAYNE
Label State: NJ
Label Zip Code: 07470
Label Country: US
Label Emergency Number: (800) 228-5635 EXT. 016
Year Procured: UNK

ALDRICH CHEMICAL -- BENZO (A) PYRENE, 98%, B1008-0
MATERIAL SAFETY DATA SHEET
NSN: 681000N065303
Manufacturer's CAGE: 60928
Part No. Indicator: A
Part Number/Trade Name: BENZO (A) PYRENE, 98%, B1008-0

General Information

Company's Name: ALDRICH CHEMICAL CO INC
Company's P. O. Box: 355
Company's City: MILWAUKEE
Company's State: WI
Company's Country: US
Company's Zip Code: 53201
Company's Emerg Ph #: 414-273-3850
Company's Info Ph #: 414-273-3850
Record No. For Safety Entry: 001
Tot Safety Entries This Stk#: 001
Status: SMJ
Date MSDS Prepared: 05JAN95
Safety Data Review Date: 23OCT95
MSDS Serial Number: BZRGR

Ingredients/Identity Information

Proprietary: NO
Ingredient: BENZO(A)PYRENE (CERCLA)
Ingredient Sequence Number: 01
Percent: 98
NIOSH (RTECS) Number: DJ3675000
CAS Number: 50-32-8
OSHA PEL: 0.2 MG/M3
ACGIH TLV: A2

Physical/Chemical Characteristics

Appearance And Odor: YELLOW GREEN POWDER.
Boiling Point: 923F,495C
Melting Point: >351F,>177C

Fire and Explosion Hazard Data

Extinguishing Media: WATER SPRAY, CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.
Special Fire Fighting Proc: WEAR NIOSH/MSHA APPROVED SCBA & FULL PROTECTIVE EQUIPMENT (FP N).
Unusual Fire And Expl Hazrds: NONE SPECIFIED BY MANUFACTURER.

Reactivity Data

Stability: YES
Cond To Avoid (Stability): NONE SPECIFIED BY MANUFACTURER.
Materials To Avoid: OXIDIZING AGENTS.
Hazardous Decomp Products: CARBON MONOXIDE, CARBON DIOXIDE.
Hazardous Poly Occur: NO
Conditions To Avoid (Poly): NOT RELEVANT

Health Hazard Data

LD50-LC50 Mixture: NONE SPECIFIED BY MANUFACTURER.
Route Of Entry - Inhalation: YES
Route Of Entry - Skin: YES
Route Of Entry - Ingestion: YES
Health Haz Acute And Chronic: ACUTE:HARMFUL IF SWALLOWED, INHALED OR ABSORBED THROUGH SKIN. MAY CAUSE EYE IRRITATION. MAY CAUSE SKIN IRRITATION. SKIN LUNGS. TO THE BEST OF MANUFACTURER'S KNOWLEDGE, THE CHEMICAL, PHYSICAL

& TOX PROPERTIES HAVE NOT BEEN THORO INVESTIGATED.
Carcinogenicity - NTP: YES
Carcinogenicity - IARC: YES
Carcinogenicity - OSHA: NO
Explanation Carcinogenicity: BENZO (A) PYRENE:IARC MONO, SUPP, VOL 7, PG 56, 1987:GROUP 2A. NTP 7TH ANNUAL RPT ON CARCINS. 1994:ANTIC TO BE (SUP DAT)
Signs/Symptoms Of Overexp: SEE HEALTH HAZARDS.
Med Cond Aggravated By Exp: NONE SPECIFIED BY MANUFACTURER.
Emergency/First Aid Proc: EYES:FLUSH WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES. SKIN:FLUSH WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES. INHALATION: REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. INGESTION:WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS. CALL A PHYSICIAN IMMEDIATELY.

Precautions for Safe Handling and Use

Steps If Matl Released/Spill: EVACUTE AREA. WEAR NIOSH/MSHA APPROVED SCBA, RUBBER BOOTS AND HEAVY RUBBER GLOVES. WEAR DISPOSABLE COVERALLS AND DISCARD THEM AFTER USE. SWEEP UP, PLACE IN BAG & HOLD FOR WASTE DISP. VENT AREA & WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.
Neutralizing Agent: NONE SPECIFIED BY MANUFACTURER.
Waste Disposal Method: DISSOLVE OR MIX THE MATERIAL WITH A COMBUSTIBLE SOLVENT AND BURN IN A CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER. OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.
Precautions-Handling/Storing: DO NOT BREATHE DUST. DO NOT GET IN EYES, ON SKIN, ON CLOTHING. CARCINOGEN. MUTAGEN. TERATOGEN. KEEP TIGHTLY CLOSED. STORE IN A COOL, DRY PLACE.
Other Precautions: NONE SPECIFIED BY MANUFACTURER.

Control Measures

Respiratory Protection: WEAR APPROPRIATE NIOSH/MSHA APPROVED RESPIRATOR.
Ventilation: USE ONLY IN A CHEMICAL FUME HOOD.
Protective Gloves: CHEMICAL-RESISTANT GLOVES.
Eye Protection: ANSI APPROVED CHEM WORKERS GOGGS (FP N).
Other Protective Equipment: ANSI APPROVED EMERGENCY EYE WASH AND DELUGE SHOWER (FP N). OTHER PROTECTIVE CLOTHING.
Work Hygienic Practices: WASH THOROUGHLY AFTER HANDLING.
Suppl. Safety & Health Data: EXPLAN OF CARCIN: CARCINOGEN. ANIMAL:SKIN, LUNG, LIVER.

Transportation Data

Disposal Data

Label Data

Label Required: YES
Technical Review Date: 23OCT95
Label Status: G
Common Name: BENZO (A) PYRENE, 98%, B1008-0
Chronic Hazard: YES
Signal Word: WARNING!
Acute Health Hazard-Moderate: X
Contact Hazard-Moderate: X
Fire Hazard-Slight: X
Reactivity Hazard-None: X
Special Hazard Precautions: TOXIC. ACUTE:HARMFUL IF SWALLOWED, INHALED OR ABSORBED THROUGH SKIN. MAY CAUSE EYE IRRITATION. MAY CAUSE SKIN IRRITATION. CHRONIC:CANCER HAZARD. CONTAINS BENZO(A)PYRENE WHICH IS LISTED AS AN ANIMAL LUNG, SKIN AND LIVER CARCINOGEN (FP N). MAY ALTER GENETIC MATERIAL. TERATOGEN. TARGET ORGAN(S):SKIN, LUNGS. TO THE BEST OF MANUFACTURER'S KNOWLEDGE, THE CHEMICAL, PHYSICAL & TOX PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.

Protect Eye: Y
Protect Skin: Y
Protect Respiratory: Y
Label Name: ALDRICH CHEMICAL CO INC
Label P.O. Box: 355
Label City: MILWAUKEE
Label State: WI
Label Zip Code: 53201
Label Country: US
Label Emergency Number: 414-273-3850

ATTACHMENT I

HEAVY EQUIPMENT CERTIFICATION

ATTACHMENT I
HEAVY MACHINERY CERTIFICATION

1. PURPOSE

The purpose of this procedure is to present the minimum safety performance requirements for the operation of heavy equipment on Earth Tech projects. Project Managers are responsible for ensuring all equipment is certified and that the attached Machinery and Mechanized Equipment form has been submitted by equipment owners.

2. GENERAL REQUIREMENTS

Subcontractor equipment shall comply with all applicable requirements for material handling heavy equipment contained in 8 CCR Sections 1590-1596. Heavy equipment includes, but is not limited to, drill rigs, front end loaders, backhoes/skiploaders, scrapers, trackhoes, bulldozers, and similar equipment used for the implementation of the project Statement of Work.

2.1 EQUIPMENT SAFETY INSPECTIONS

The following presents general guidelines for certifying equipment is in safe operating condition before activities commence at the Site and during Site operations. The following guidelines are not meant to be all inclusive.

- All machinery and mechanized equipment will be certified to be in safe operating condition (using the attached form) by a competent individual seven days prior to onsite operation, and is valid for 1 year.
- Equipment will be inspected on a daily basis by the owner/operator and daily logs will be maintained. All discrepancies shall be corrected prior to placing the equipment in service.
- Inspections shall include, but are not limited to: all hydraulic lines and fittings for wear, damage or leakage, all cable systems and pull ropes for damage and proper installation, exhaust systems, brake systems, and drill controls, etc.
- Preventive maintenance shall be conducted for all equipment according to manufacturer recommendations or the Subcontractor's internal policies, schedules, and equipment SOPs.
- Machinery and mechanized equipment shall be operated only by designated qualified persons.
- Records of tests and inspections shall be maintained at the Site by the contractor, and shall be made available upon request of the designated authority, and shall become part of the official project file.
- Equipment not found to be in safe operating condition, or when a deficiency which affects the safe operation of the equipment, shall immediately be taken out of service and its use prohibited until safe conditions have been corrected.
- All equipment shall be kept in the exclusion zone until work or the shift has been completed. Equipment will be decontaminated within designated decontamination areas.
- Equipment with an obstructed rear view must have an audible alarm that sounds when equipment is moving in reverse.

TO: Earth Tech DATE:

FROM:

Project Name:
Project Location:

This form provides certification of machinery and mechanized equipment to be used on the referenced project for the following work:

Description of equipment work:	
Project Site:	
Subcontractor providing equipment: Address:	
Dates (duration) of equipment work:	

Inspection and certification of machinery and mechanized equipment, as required by Earth Tech has been made prior to, but within seven calendar days advance of, use on the project site. Re-certification will be required for equipment that is used on the project site for more than one year.

	Identification of equipment (make, model, serial no.)	Date of Certification
1		
2		
3		

The above listed equipment has been inspected and tested as indicated above, and is CERTIFIED TO BE IN SAFE OPERATING CONDITION BY THE FOLLOWING COMPETENT INDIVIDUAL:

Name		Title	
Company			
Signature		Date	

If there are any questions regarding this certification, please contact the following Earth Tech representative:

ATTACHMENT J

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE

ATTACHMENT J
HAZARDS OF ELECTROMAGNETIC RADIATION ORDNANCE

On-site use of devices that emit electromagnetic radiation (EMR) presents a significant hazard due to susceptibility of electro-explosive devices (EED) to accidental detonation by EMR. EMR-emitting devices include many of the common types of communication equipment and navigation aids regularly employed on site (e.g., cellular telephones, two-way radios). While curtailment in use of these devices is preferable, some on-site activities are required. Accordingly, the ordnance and explosives (OE) hazard distance (referred to as the safe separation distance [SSD]) must be determined for each device that emits or produces EMR.

Table F-1 presents the formulas used to calculate SSD, based on the emission frequency of the EMR and the following parameters:

D = SSD (in feet)
F = EMR frequency (in megahertz [MHz])
P = EMR output power (in watts)
G = absolute (numerical) power gain ratio of the transmitting antenna (unitless).

Table F-1. Safe Separation Distance Formulae

Frequency Range	SSD Formula
$f < 0.02$ MHz	$D = 0.093 \times (PG)^{0.5}$
$0.02 \text{ MHz} \leq f < 0.1$ MHz	$D = 4.63f \times (PG)^{0.5}$
$0.1 \text{ MHz} \leq f < 2.0$ MHz	$D = 18f \times (PG)^{0.5}$
$2.0 \text{ MHz} \leq f < 32$ MHz	$D = 90 \times (PG)^{0.5}$
$32 \text{ MHz} \leq f < 1{,}000$ MHz	$D = 1{,}200/f \times (PG)^{0.5}$

The following rules should be observed when calculating SSDs:

Rule 1: Where emissions occur over a range of frequencies, the SSD will be determined for the highest and lowest frequency in the range, and the greater value accepted as the SSD for the device.

Rule 2: If the device can be manually set to operate at different frequencies, a separate distance can be calculated for each operating frequency. If frequencies can be changed automatically, the set of available frequencies should be treated as a range and analyzed per Rule 1.

Calculated SSDs for each device should be recorded on an SSD Log that has been established for the site. The information should also bew affixed to each device so that it is readily identifiable by device operators.

APPENDIX G

MINIMUM SEPARATION DISTANCE CALCULATIONS

CESPK-DE 29 September 2000

Memorandum for Record

Subject: Recommendations for Minimum Separation distances (MSD) for Tourtelot OE Removal Action, Former Benicia arsenal.

Summary: A technical evaluation of the Most Probable Munitions (MPM) and Minimum Safe Distance has been completed based on the latest available information, and the guidance that would apply if the Corps of Engineers were conducting the work as a Formerly Used Defense Site (FUDS). Guidance applicable to OE removals at FUDS sites includes guidance from the Department of Defense (DOD), Department of Army (DA), U.S. Army Corps of Engineers (USACE) and Corps Huntsville Center (HNC). The analysis and findings would be applicable to Sectors 3A and 3B that were recommended for a removal action in the Engineering Evaluation/Cost Analysis (EE/CA) prepared by HNC for the FUDS program.

We have identified the appropriate MPM and MSD for each of the work areas within Sectors 3A and 3B that the Corps of Engineers would use if it were executing the removal action. These are based on an un-armed 37 MM projectile and an un-armed 60 MM Mortar.

The City of Benicia is planning to do additional actions outside the areas recommended for removals in the EE/CA. These areas do not fall within the normal Corps of Engineers OE removal categories and the normal MSD definition process would not be applicable.

However, if the removal action in the EE/CA Sector 3A or Sector 3B removal areas resulted in finding live ordnance items at the edge of the planned removal areas, the normal Corps of Engineers procedure would be to incrementally expand the removal action into the adjacent area until no further OE items are located. During the search for OE items in such an expansion area, the MSD for the MPM in the adjacent Sector A or Sector B area would continue to be used.

The role of CESPK in these efforts is limited to that of providing guidance, technical reviews, site support, and advice to the City of Benicia as described in the MOA with the City of Benicia. Approval of work plans and the adoption of appropriate MSD will be up to the authorities responsible for conducting the OE removal and approving the actions.

Technical Evaluation: In Sector 3A, a 60 MM mortar has been identified as the MPM, and would have a fragmentation distance of 1080 feet. Since the munitions are not likely to be fuzed and armed, it would be appropriate to a 1 Hazardous Fragment in 600 Square Feet MSD with a minimum separation distance of 200 feet.

The prior Demolition area portions of Sector 3A Sector 3B is an area that has identified a 37 MM projectile as the MPM. A radius of 1250 feet from the demolition pit has been used to define the potential kick-out area from the pit. The 37 MM projectile has a fragmentation distance of 1181 feet. Since the munitions are not likely to be armed, it would be appropriate to a 1 Hazardous Fragment in 600 Square Feet MSD with a minimum separation distance of 234 feet.

Engineering controls should be employed in these areas to reduce the blast distances from any intentional detonation.

Conclusions and Recommendations:

1. Public safety must be a leading concern for the interested parties and the Corps of Engineers in proceeding with the OE response. Public officials, public safety personnel, UXO workers, and public living and working near the site must be made aware of the hazards and responses being made to reduce them.

2. The maximum fragmentation distance calculations for the 37 MM and 60 MM MPM's (if this were a Corps of Engineers project) would be that of 1181 feet and 1080 feet, respectively. Sectors 3A and 3B would be appropriate for reduction of the MSD to a 1 Hazardous Fragment in 600 Square Feet MSD based on the MPM being unfuzed and unarmed. The reduction to a 1 Hazardous Fragment in 600 Square Feet MSD is an increased risk to the public that must be assumed by those officials approving the adoption of this reduced MSD.

3. We recommend that the public be made aware of the (MSD) and the additional hazards that they may be exposed to in the event of an unintentional detonation when using the 1 Hazardous Fragment in 600 Square Feet MSD.

4. Prior to conducting OE removal actions at this site a detailed OE Removal Work Plan will need to be developed, reviewed and approved by the appropriate agencies. The work plan will need to include a Community Safety Plan that addresses issues of public safety, coordination, notification and measures to deal with planned evacuations for both unintentional and intentional detonations. The work plan also needs to include a Contingency Action Plan to evaluate the potential for additional OE items discovered that would change the recommended MSD based on the present MPM, and for intentional detonations.

5. If at any time a UXO or a larger MPM is discovered, work must be halted and notifications be made to the appropriate authorities, who must reevaluate the MPM, MSD and the appropriateness of using a 1 Hazardous Fragment in 600 Square feet MSD. This evaluation process would establish new MSD based on the new MPM. A new evaluation and approval for a 1 Hazardous Fragment in 600 Square Feet MSD would need to be completed and be in place before any maximum fragment distance could be reduced.

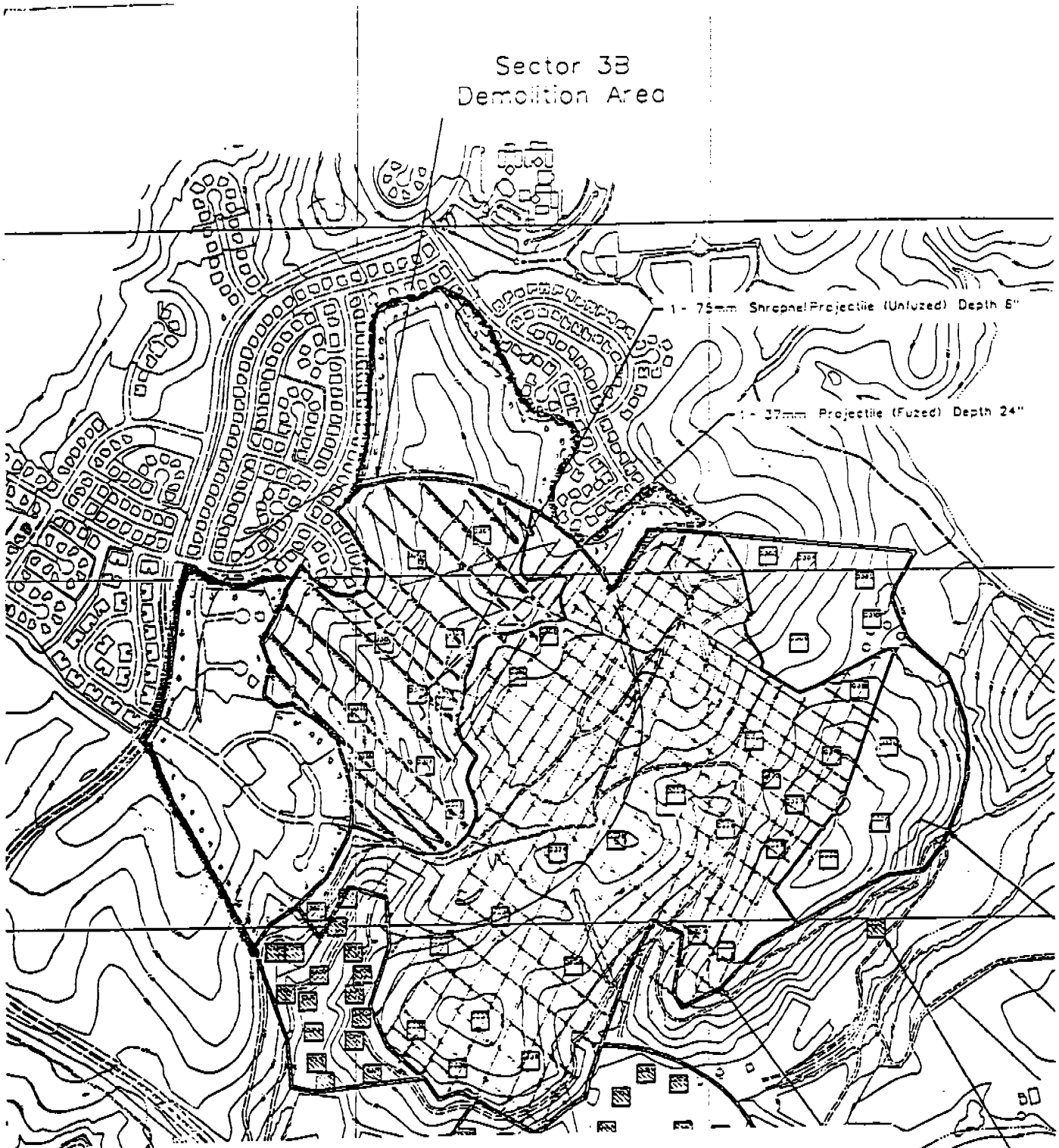


FIGURE 1. Most Probable Munitions (MPM) and Minimum Separation Distance(MSD) for Tourtelot Property, Sectors 3A and 3B.

KEY

....37 MM projectile MPM, 1 Hazardous Fragment in 600 Sq. Feet. MSD = 234 Feet

....60 MM mortar MPM, 1 Hazardous Fragment In 600 square Feet MSD = 200 Feet

....Additional DTSC Areas, see increment...
OE Expansion from Edge of EE CA Sector A...
Live OE at edge MSD same as edge of EE CA Sector...

TRANSMITTAL SHEET

US Army Corps
of Engineers
Sacramento District

RECEIVED BY
CITY ATTORNEY'S OFFICE
DEC 20 2000
CITY OF BENICIA

DATE: 18 December 2000

TO: Heather McLaughlin
City of Benicia
250 East L Street
Benicia, CA 94510

PROJECT: Benicia Tourtelot Cleanup Project
CONTRACT NO: NA
INSTALLATION: Benicia Arsenal

THE ENCLOSED DOCUMENTS ARE BEING TRANSMITTED TO YOU FOR:

[X] COORDINATION [X] INCORPORATION [ ] INFORMATION

DOCUMENTS ENCLOSED:

1. Responses to DTSC's follow-up questions (email dated 18 October 2000) on USACE Memorandum For Record dated 29 September 2000. Subject: Recommendations for Minimum Separation Distance for Benicia Tourtelot OE Removal Action.

REMARKS:

Heather,

Attached are the USACE responses to DTSC's follow-up questions on the 29 September 2000 Memorandum for Record, Subject: Recommendations for Minimum Separation Distances for Tourtelot OE Removal Action. Please note that I have forwarded a copy of the attached Memorandum for Record to Stewart Black of the DTSC. Please forward to any interested parties.

If you have any questions regarding these responses, please call me at (916) 557-7906.

Bruce

cc: John Esparza, Technical Team Lead
Stewart Black, Project Manager, DTSC

If enclosures are not as listed, please notify us at once.

FROM: Bruce Handel
Project Manager

CESPK-PM-H
1326 J Street
Sacramento, CA 95814-2922
Tel: (916) 557-7906
Fax: (916) 557-7885

CESPK-PM-H (200a) 15 December 2000

MEMORANDUM FOR RECORD

SUBJECT: Response to follow-up questions (transmitted via email on 18 October 2000) on the 29 September 2000 Memorandum for Record, Subject: Recommendations for Minimum Separation Distances (MSD) for Tourtelot OE Removal Action, Former Benicia Arsenal.

1. REFERENCES:

a. DOD 6055.9-STD, DOD Ammunition and Explosives Safety Standards, July 1999.

b. Memorandum of Agreement (MOA) between the City of Benicia and the U.S. Army Corps of Engineers, District, Sacramento, February 1999.

c. HNC-ED-CS-S-98-1, Methods for Predicting Primary Fragmentation Characteristics of Cased Explosives, January 1998.

d. HNC-ED-CS-S-98-2, Method for Calculating Range to No More than One Hazardous Fragment per 600 Square Feet, January 1998.

e. Memorandum of Record, United States Army Corps of Engineers (CESPK-DE), 29 September 2000, subject: Recommendations for Minimum Separation Distances (MSD) for Tourtelot OE Removal Action, Former Benicia Arsenal.

f. Memorandum, United States Army Corps of Engineers (CEHNC-OE-CX), 02 March 2000, subject: Determination of Appropriate Safety Distances on Ordnance and Explosives (OE) Project Sites, OE Center of Expertise (CX) Interim Guidance Document 00-01.

g. Draft Work Plan for the Ordnance and Explosive Removal Actions, Sectors 2, 4 and 5, Former Benicia Arsenal, Benicia, CA, July 2000. Prepared by EODT on behalf of the U.S. Army Engineering & Support Center, Huntsville, Alabama.

h. Draft Remedial Investigation/Feasibility Study, Toutelot Cleanup Project, Benicia, California, November 16, 2000. Prepared by Earth Tech.

2. ATTACHMENTS:

A. United States Army Corps of Engineers, CEHNC-ED-CS-S, calculations of Minimum Separation Distances, 60 mm M49A3, 3 April 2000.

B. United States Army Corps of Engineers, CEHNC-ED-CS-S,

c. Areas of Concern. The analysis and findings originally presented would be applicable to Sectors that were recommended for a removal action by the USACE; Sectors 3A and 3B were recommended for a removal action by the USACE in the Engineering Evaluation/Cost Analysis (EE/CA) prepared under the FUDS program.

It is understood that OE/UXO investigation and removal activities may extend outside of Sector 3A and 3B. Furthermore, as originally outlined in reference (e), and as provided in attachment (e), USACE has established methods and procedures to address expansion (and/or reduction) of the area of concern; during the search of OE items in such an expansion area, the MSD for the MPM in the adjacent Sector A or B area would continue to be used (see figure 3 of attachment (e)). In general however, the minimum separation distance may be reduced to fit the situation but in no case will the minimum separation distance be less than the range to no more than 1 hazardous fragment per 600 square feet, 200 feet, or K50 based on overpressure, whichever is greater (reference (f)).

Under the aforementioned EE/CA, the USACE did not recommend a removal action at the D-1 Area, western portion of the south valley, the entire North Valley, the Ridge areas and/or surrounding community. Theses areas are identified under the on-going OE RI/FS and the USACE are providing recommended MSDs at the request of the City of Benicia (See attachment (e)).

4. POINTS OF CONTACT: If you need additional information, please contact Mr. AR Smith at 916.557.6973 or Mr. Bruce Handel at 916.557.7906, Project Manager, CESPK-PM-H.

cc: Project File

ATTACHMENT A

Minimum Separation Distances
Ft. Ord
60 mm M49A3
3 April 2000

REQUESTED BY: Patti Berry
PREPARED BY: Michelle Crull, PhD, PE

This form shows calculated distances only. It does not constitute approval. Concurrence of CEHNC-OE-S is required to determine the applicable distance for a specific site.

In accordance with (IAW) OE Center of Expertise Interim Guidance Document 98-08, use of the range to no more than 1 hazardous fragment/600 sq ft as the minimum separation distance for accidental detonations requires written justification, a risk analysis, calculation of this distance by CEHNC-ED-CS-S, and concurrence of CEHNC-OE-S.

CALCULATIONS FOR UNINTENTIONAL DETONATIONS

Maximum Fragment Range = 1080 ft
Range to No More Than 1 Hazardous Fragment/600 sq ft = 200 ft
Range to 0.9 psi Overpressure = 42 ft

IAW OE Center of Expertise Interim Guidance Document 98-08, the minimum separation distance for intentional detonations may not be less than the default distance provided in DoD 6055.9-STD or the maximum fragment range or the K328 overpressure distance.

CALCULATIONS FOR INTENTIONAL DETONATIONS

Maximum Fragment Range = 1080 ft
K328 Overpressure Range = 277 ft

The primary fragmentation characteristics used in the calculation of the values listed above were computed IAW CEHNO-ED-CS-S-98-1. The maximum fragment range was calculated using the maximum weight fragment and the initial velocity from these characteristics in the computer software TRAJ. The range to no more than 1 hazardous fragment/600 sq ft was calculated IAW CEHNC-ED-CS-S-98-2.

SIGNATURES:

Michelle Crull 4/3/00
Subject Matter Expert

CEHNC-ED-CS-S Branch Chief

ATTACHMENT 4

Public Withdrawal Distance (PWD)
Camp Beale, California
31 August, 1999

MUNITION: 37 mm MKII
REQUESTED BY: Bill Sargent
PREPARED BY: Douglas E. Grant, P.E.

This form shows calculated distances only. It does not constitute approval. Concurrence of CEHNC-OE-S is required to determine the applicable distance for a specific site.

In accordance with (IAW) OE Center of Expertise Interim Guidance Document 98-08, use of the range to no more than 1 hazardous fragment/600 sq ft as the PWD for accidental detonations requires written justification, a risk analysis, calculation of this distance by CEHNC-ED-CS-S, and concurrence of CEHNC-OE-S.

ACCIDENTAL DETONATIONS

Maximum Fragment Range = 1181 ft
Range to No More Than 1 Hazardous Fragment/600 sq ft = 200 ft
Range to 0.9 psi Overpressure = 43 ft

IAW OE Center of Expertise Interim Guidance Document 98-08, the PWD for intentional detonations may not be less than the default distance provided in DoD 6055.9-STD or the maximum fragment range or the K328 overpressure distance.

INTENTIONAL DETONATIONS

Maximum Fragment Range = 1181 ft
K328 Overpressure Range = 282 ft

The primary fragmentation characteristics used in the calculation of the values listed above were computed IAW CEHNC-ED-CS-S-98-1. The maximum fragment range was calculated using the maximum weight fragment and the initial velocity from these characteristics in the computer software TRAJ. The range to no more than 1 hazardous fragment/600 sq ft was calculated IAW CEHNC-ED-CS-S-98-2.

SIGNATURES:

Douglas E. Grant
Subject Matter Expert

William H. Rohr Jr. 1 SEP 99
CEHNC-ED-CS-S Branch Chief

ATTACHMENT C[1]

DATE	PROJECT NAME	17600 DISTANCE	MPM
11 Jan 98	Camp Grant	219	3" Stokes
05 May 98	Castner	341	105 mm
15 Jul 98	Camp Bonneville	341	105 mm
13 Oct 98	Benicia - Ordnance Bunkers	400	MK II Grenade
13 Oct 98	Benicia - Revetment Area	200	37 mm
14 Oct 98	Fort Dix - Correctional Facility	234	81 mm
22 Jan 99	Panama - Ranges 7, 7A, 8 and 10	341	105 mm
19 Feb 99	Duck	302	2.75" rocket
26 Feb 99	Camp Grant	219	3" stokes
04 Mar 99	Spring Valley - OU3	200	75 mm Mk II
29 Apr 99	Jefferson Proving Grounds - Sulfur Area	341	105mm
24 Jun 99	Illinois Ord Plan	200	M1A1 AT Mine
06 Jul 99	Brooksville-Rocket Range	200	2.36" rocket
06 Jul 99	Brooksville- Mortar Range	234	81 mm
10 Sep 99	Mallinckrodt - Stockpile 2	310	100 lb parrot
15 Sep 99	Ft. McClellan - Eastern Bypass	200	60 mm
15 Oct 99	Papohaku	302	2.75" rocket
19 Oct 99	Nansemond - Tidewater Community College	200	No Ordnance
29 Oct 99	Nansemond - Area O	361	4.5" rocket
08 Feb 00	Nansemond-anomaly investigation	200	No Ordnance
11 Feb 00	Camp Ellis - Area B	200	60 mm
14 Mar 00	Conway-Ranges IV & VII	275	20 lb Frag Bomb
16 Mar 00	Guam	299	5"/38 cal
05 Apr 00	Hohenfels	250	90 mm
06 Apr 00	Ft. Benning	400	Mk II Grenade
19 Apr 00	Nansemond - Area O and Kick Out Area	361	4.5" rocket
20 Apr 00	CGS	200	No Ordnance

[1]U.S. Army Corps of Engineers, Ordnance and Explosive (OE) Design Center, Huntsville, CEHNC-OE-DC. Data is current through April 2000.

ATTACHMENT D

Response to Follow up Questions on the U.S. Army Corps of Engineers Recommended Minimum Separation Distance (MSD) for Ordnance and Explosives (OE) Removal Actions at the Tourtelot Site, Benicia, California.

DTSC has reviewed Colonel Walsh's letter and the attached Memorandum for Record and have the following questions and request for additional information:

General Comments/Questions

1. The map contained in the Memorandum for Record is unclear as to which MSD should be used in the areas where Sectors 3a and 3b overlap. Please clarify which MSD should be used in the overlap areas.

Response: To further clarify the MSDs, the single map contained in the 29 September 2000 MFR has been replaced with three separate color-coded maps (figure 1, 2, & 3). The maps reflect a MSD of 200 feet for Sector (3a) and Sector (3b). The original MSD Memorandum For Record (MFR) of 29 September 2000 has been revised by adding the three figures (see attachment (e)).

2. The ACOE has been involved in project meetings and is aware that the proposed OE/UXO scanning and clearance activities for the Tourtelot project extend outside of Sector 3a and 3b. However, the ACOE has not provided an approved MSD for a significant portion of the Tourtelot site targeted for OE/UXO investigation/remediation. Please provide DTSC with the ACOE approved MSD for UXO/OE clearance work to be performed on the entire Tourtelot Site including the D-1 Area, western portion of the south valley, the entire North Valley, the Ridge areas and surrounding community (if needed).

Response: A detailed response has been provided under section 3(c) of the 11 December 2000 MFR.

3. It appears that the MSD for remediation of TNT at the site has not been included in the this evaluation, as previously requested. Please provide this information.

Response: The USACE acknowledges DTSC's previous request for a MSD for remediation of TNT stripe located at the Tourtelot site,

The USACE has recently received the information necessary to calculate the net explosive weight under reference (h). Also, the USACE-SPK has just received the necessary guidance to calculate an MSD for this situation. The calculations are currently being developed and will be provided to the City of Benicia at a later time under separate cover.

4. Please provide DTSC a copy of the color maps (including any necessary revisions as requested in 1, 2 and 3 above) identifying the MSD locations. It is difficult to understand the maps in black and white.

Response: See response to comment number 1 above.

5. It is unclear how the ACOE has established the approved MSD contained in Colonel Walsh's letter. Please provide the supporting documentation and calculations for the use of the "Range to No More Than One Hazardous Fragment per 600 Square Feet" calculation. Please include a list of similar projects which have been successfully completed using an MSD calculated using the reduced "Range to No More Than One Hazardous Fragment per 600 Square Feet" calculation recommended for the Tourtelot site. Also, please include the number of accidents that have occurred when clearing OE on similar sites?

Response: Supporting documentation and associated calculations have been provided (see attachment (A) and (B)). See attachment (C) for projects that have been successfully completed using a reduced 'Range to no more than one hazardous fragment per 600 square feet' MSD.

A survey of reported accidents that have occurred when clearing OE while employing a 'Range to No More Than 1 Hazardous Fragment per 600 square feet' MSD has been completed by U.S. Army Corps of Engineers, Ordnance and Explosives (OE) Design Center, OE Safety Office (CEHNC-OE-S). There have been no reported accidents involving OE clearance operations while employing a 1/600 MSD (see www.hnd.usace.army.mil).

6. Please explain how the recent discovery of a potentially live mortar, tail fin section has been addressed in the MSD calculations. The tail fin was discovered well outside of the 1250' radius suggested by the ACOE. What impact, if any could this discovery have on the calculations and recommendations provided by the ACOE.

Response: Under USACE procedures if during the design stage of a UXO/OE removal or investigation project new information is discovered, this information is assessed and modifications to the design incorporated as required. The process of managing and acting upon new information is further refined during field execution. USACE regulations governing execution of UXO/OE removal or investigation projects, require that information on the number, type and condition of UXO/OE encountered is assessed daily and acted upon immediately if necessary.

On December 5, 2000 the USACE provided a detailed response to Benicia City Attorney concerning the recent discovery of the tail fin. Any questions or concerns posed by the DTSC that are not addressed in the December 5, 2000 response should be addressed in the Tourtelot RI/FS document (reference (h)) as required by the DTSC Order No. I/SE 98/99-011.

Specific Questions

7. Page 1: Under the Summary: section; paragraph 2. Indicates that the appropriate Most Probably Munition (MPM) for Sector 3a and 3b are an un-armed 60 MM mortar and an un-armed 37 MM projectile, respectively. Please provide documentation to confirm that the 60 MM Mortar found in Sector 3a should be classified as un-armed and was not primed, fuzed and/or fired. Information available to DTSC also indicated that the 60 MM mortar that was found was a high explosive (HE) round. Please confirm that a 60 MM HE mortar was used as the MPM to determine an appropriate MSD in Sector 3a. The map contained in the Memorandum for Record indicates that the 37 MM projectile found in Sector 3b was fuzed. Please provide the justification used by the ACOE to classify this ordnance as un-armed when determining the appropriate MSD for Sector 3b.

Response: The key concept that must be understood by all parties is the impact of classifying an item as 'un-armed' versus 'armed' and the use of the 'Range to No More Than 1 Hazardous Fragment per 600 square feet'.

If an item is classified as 'armed', then the use of 'Range to No More Than 1 Hazardous Fragment per 600 square feet' is not an option under Department of Army regulations. If however, the item is classified as 'un-armed' the option to use the 'Range to No More Than 1 Hazardous Fragment per 600 square feet' is still available.
Whether the item is 'fuzed' is not considered when deciding to

assess the 'Range to No More Than 1 Hazardous Fragment per 600 square feet' option. Moreover, the 37 mm projectile has an internal fuze and must be considered 'fuzed' under normal USACE procedures; hence the identification of 'fuzed' in the MFR map.

The USACE, Ordnance and Explosive Design Center, Structural Branch (CEHNC-ED-CS-S) employed 'latest available information' and professional judgment to classify the MPM of a 37 mm projectile and 60 mm mortar as 'un-armed'. The justification to assign this classification is based on:

(a) The item likely originated from a demolition pit and under normal demolition procedures the item would have to be 'un-armed' in order to allow movement of the item to a demolition pit location; and

(b) The lack of historical records to indicate live fire (i.e. range activity) ever occurred at the Benicia Arsenal.

The USACE acknowledges that information about the 60 mm mortar round indicated that it was a high explosive (HE). USACE also confirms the 60 mm mortar HE was used as the MPM for Sector 3a.

Note: See Attachment (A) and (B) and reference (a) for a detailed description of the relationship between 'Maximum Fragment Range', 'Range to No More Than 1 Hazardous Fragment per 600 square feet', 'Range to 0.9 psi Overpressure' and 'K328 overpressure distance'.

8. Page 1: Under the <u>Summary:</u> section; paragraph 5. Please refer to the Imminent and/or Substantial Endangerment Determination and Remedial Action Order issued by DTSC for the Tourtelot Property on June 1, 1999. The United States Department of the Army is jointly and severally responsible for carrying out all actions required by the order. The CESPK has been attending project meetings, providing technical direction and acting as the official representative of the United States Department of the Army on all aspects of the Tourtelot project. In this capacity CESPK has assumed a much broader scope of responsibility in the Tourtelot matter then just advisor to the City of Benicia. This responsibility includes, but is not limited to the safety of personnel working at the site and public safety of area residents.

Response: A question or comment was not provided. If the reviewer intended to pose a question or comment please revise

accordingly. Please note however, the USACE respectively request that any correspondence related to this subject be forwarded directly to the USACE, Sacramento District Legal counsel.

9. MSD - Please provide the supporting calculation for the MSD in both Sectors 3a and 3b. The 200' MSD appears to be a default value.

Response: Again, the reviewer is referred to Attachment (A) and (B) for supporting calculations. As outlined in reference (f), MSDs smaller than 200' are not allowed under USACE regulations, even though calculations may reflect shorter distances (also see reference (a)).

10. Page 1: Under the Technical Evaluation: section; paragraph 2. Please define what you mean by, "A radius of 1250 feet from the demolition pit has been used to define the potential kick-out area from the pit". Specifically what does the phrase "potential kick-out area represent" mean. Also please define why only one pit has been used to defined the 1250' kick-out when four demolition pits have been identified.

Response: The Technical evaluation has been revised by focusing the discussion on the MPM for each Sector rather than sub-areas within a Sector. The 11 December 2000 MFR reflects this change.

Note: the 1,250-foot distance was employed during the approved EE/CA investigation. We knew little about the type of ordnance that was used at the demolition site so we selected the 1250 default distance as a reasonable distance for limiting our Sector size. This may or may not be an appropriate distance for a removal action, but the solution is to expand the clearance area if we're still finding ordnance at the limits of the area.

Potential kick-out area means an area around the demolition pit within which we would expect to find kick-outs of live ordnance from detonations. The analysis focused on the 'worst case' or largest demolition pit; this is consistent with UXO/OE removal operations where 'worst case' areas would be addressed prior to other areas within the Sector. Moreover, the other 4 demolition pits are in close proximity to the primary pit.

11. Page 2: Conclusions and Recommendations: Item number 2. Please define qualitatively and quantitatively the increase risk to the public identified in the statement; "The

reduction to a 1 Hazardous Fragment in 600 Square Feet MSD is an increase risk to the public that must be assumed by those officials approving the adoption of this reduced MSD".

Response: Determining, quantitatively, the risk from unintentional and intentional detonations is a major challenge to the Department of Defense including the Department of Army. Reaching consensus on the methods, procedures and fundamental assumptions of a quantitative risk assessment is an on-going National effort and major focus of the Department of Defense, regulatory agencies and stakeholders. While much progress has been made in this area, a quantitative answer cannot be provided at this time.

Qualitatively, the risk at maximum fragment distance is minimal (less than 1 percent probability), whereas at the 1/600 distance there's a 1 percent probability of a person in the open being struck by a hazardous fragment (see Reference (a) for additional detail).

12. Page 2: <u>Conclusions and Recommendations:</u> Item number 2. Additional information which will be required to understand the increased risk to the public include:
    1. What is the underlying assumption for choosing the 1 hazardous fragment in 600 square feet as an acceptable risk?

Response: As discussed earlier, the use of professional judgment lead to the underlying assumption that the items are unfired and therefore un-armed.

Reference (a) further discusses the development of, and criteria for, a 'Range to No More than 1 Hazardous Fragment per 600 Square Feet (1/600 Distance)'.

    2. Has the Army used this calculation as the basis for an MSD in other cleanup sites near civilian residential areas?

Response: See attachment (C) for projects that have been successfully completed using a reduced 'Range to no more than one hazardous fragment per 600 square feet' MSD.

    3. Please be sure to include a table to illustrate how the risk will vary with change in distance from the detonation point. For example if the MSD is 234' what

is the risk to an individual standing at 235' from the detonation or at 200', 300', 400'...

Response: See response to question 11 and the following table is provided.

Table 1
QUALITATIVE RISK VERSUS
DISTANCE AWAY FROM DETONATION POINT[A]

Detonation Point	1/600 Distance	Maximum Fragment Distance
Point Removal of OE	Increased Risk. A person (6 ft tall, 1 ft wide) taking no evasive action has a 1% probability of being struck by a hazardous fragment	Minimal risk. A person (6 ft tall, 1 ft wide) taking no evasive action has less than a 1% probability (but not zero) of being struck by a hazardous fragment

[A] Source: DOD 6055.9-STD, DOD Ammunition and Explosive Safety Standards, July 1999.

4. Also please provide information on fragment velocity and striking energy at the select distances included in the table. Since these figures will be somewhat technical please provide an example and/or illustration of what each fragment velocity and striking energy means in laymen's terms.

Response: Striking energy is related to fragment mass and velocity ($E=1/2\ mv^2$). Velocity is dependent on distance traveled and the drag coefficient. The drag coefficient is dependent on fragment weight, shape and velocity.

A hazardous fragment is one with a striking energy of 58 ft-lbs. The 58 ft-lbs criteria was approved by DDESB in April 1971 and is based on a report by the Medical Department of the Army using empirical data from WWI, WWII and the Korean war as well as experimental test data (reference (a)).

In laymen's terms, a 20 lb. bowling ball dropped on your foot from 3 feet high will impact with 60 ft-lb of energy and thus deliver the energy of a hazardous fragment. Figures may be developed upon request of the City of Benicia.

13. Page 2: **Conclusions and Recommendations:** Item number 3. Although a recommendation is made "that the public be made aware of the MSD and the additional hazards." Through our discussions with ACOE representatives it appears the Department of Defense has used the approach of smaller MSD's at other sites. Has the Department of Defense found an effective way to make the public aware of this increased risk. The Arsenal appears to be poised to use the same reduced MSD's. How is the Corps going to make the public aware of the use of the smaller MSD and the associated increase risk to them, including those areas adjacent to highway 680.

Response: For the work the Corps of Engineers is executing under the FUDS program, the method and procedures to inform the public are outlined Section 2.6 of Reference (g). The document is currently under review with DTSC and scheduled to be finalized January 01. In addition, and under the FUDS program, the USACE is developing a Community Ordnance and Explosive Safety Program, which will be presented to the Benicia City Council on 16 January 2001.

The planned method and procedures, augmented by risk communication techniques, have proven to be an effective way to communicate risk to the public.

It is anticipated, for the work executed under the Tourtelot project, the method and procedures to inform the public will be presented in an OE removal Work Plan(s) prepared as part of the RI/FS for the Tourtelot Clean Up Project. See reference (h).

14. Page 2: **Conclusions and Recommendations:** Item number 4. As discussed, the MSD will be part of the explosive safety submission to Department of Defense Explosives Safety Board (DDESB). The approval of the use of the procedure should be provide as soon as possible. This will make the OE Removal Work Plan, Community Safety Plan and Contingency Action Plan easier to review if the previously reviewed and approved procedures have been provided.

Response: A question or comment was not provided. If the reviewer intended to pose a question or comment please revise accordingly. The USACE supports your recommendation that the ESS is approved and made part of the OE Work Plan.

15. Page 2: **Conclusions and Recommendations:** Item number 5.

Based on the potential kick-out area and area 3a and 3b boundary lines, there appears to be an overlap of MSD areas around and overlooking Sector 2 and D-1. Should the MSD be revised to reflect the larger of the two MSD's in areas of overlap?

Response: As previously discussed, to further clarify the MSDs, the single map contained in the 29 September 2000 MFR has been replaced with three separate color-coded maps (figure 1, 2, & 3). The maps reflect a MSD of 200 feet for both Sectors so there is no larger MSD. The original MSD Memorandum For Record (MFR) of 29 September 2000 has been revised by adding the three figures (see attachment (e)).

16. Page 3: **Map/** The MSD for the D-1 area, the western portion of the south valley and the northern portion of the South Valley is not clearly understood. Please provide the approved MSD that should be used in these and any other undefined areas on the Tourtelot site.

Response: A detailed response has been provided under section 3(c) of the 11 December 2000 MFR. Also see Figures 1, 2, and 3 of attachment (e).

17. Please provide a discussion of "hazardous fragment."
    1. What is a "hazardous fragment"?
    2. Define what makes up a hazardous fragment?
    3. How hazardous is a "hazardous fragment"?
    4. How large is a "hazardous fragment"?
    5. What is the potential or likely damage to a person hit with a "hazardous fragment"?
    6. At what distance from the uncontrolled detonation does a piece of fragment become a "non-hazardous fragment"?

Response: A hazardous fragment is defined by DOD 6055.9-STD as one having an impact energy of 58 ft-lb or greater. The size of a hazardous fragment may be large or small. Mass and velocity determine the energy, which in turn determines whether it is a hazardous fragment, or not. At velocities achieved during detonation, fragments smaller than ¼ ounce will not be hazardous.

To give an idea of the other end of the scale, a 20 lb. bowling ball dropped on your foot from 3 feet high will impact with 60 ft-lb of energy and thus deliver the energy of a hazardous fragment.

The damage to a person hit by a hazardous fragment depends upon the shape of the fragment, the angle of impact, and whether it strikes a vital organ or not. The 58 ft-lbs is considered by DOD to be an acceptable risk. The number is a result of injury statistics gathered from WWI, WWII, and the Korean War. This is also the NATO definition of hazardous fragment.

A hazardous fragment becomes a non-hazardous fragment when the energy is less than 58 ft-lbs, which is a function of mass and velocity. Distance does not enter into the equation. See response to question 12(4).

18. What is the likely or potential property damage that could occur from frag within the identified MSD and up to the maximum fragment flight distance?

Response: There will probably be property damage, but how much damage is dependent on the size of the detonation, size of fragments, orientation of the round, depth below the surface, and other factors.

19. What is the likelihood that an uncontrolled detonation will occur?

Response: Based on professional judgment, it is very unlikely that a unintentional detonation will occur, otherwise the USACE wouldn't have proposed to reduced the MSD to 1/600.

ATTACHMENT E

CESPK-DE 11 December 2000

Memorandum for Record

Subject: Recommendations for Minimum Separation distances (MSD) for Tourtelot OE Removal Action, Former Benicia arsenal.

Summary: A technical evaluation of the Most Probable Munitions (MPM) and Minimum Safe Distance has been completed based on the latest available information, and the guidance that would apply if the Corps of Engineers were conducting the work as a Formerly Used Defense Site (FUDS). This memorandum updates the memorandum dated 29 September 2000. Guidance applicable to OE removals at FUDS sites includes guidance from the Department of Defense (DOD), Department of Army (DA), U.S. Army Corps of Engineers (USACE) and Corps Huntsville Center (HNC). The analysis and findings would be applicable to Sectors 3A and 3B, including the potential expansion area adjacent to the sectors, that were recommended for a removal action in the Engineering Evaluation/Cost Analysis (EE/CA) prepared by HNC for the FUDS program.

We have identified the appropriate MPM and MSD for each of the work areas within Sectors 3A and 3B that the Corps of Engineers would use if it were executing the removal action. These are based on an un-armed 37 MM projectile and an un-armed 60 MM Mortar.

The City of Benicia is planning to do additional actions outside the areas recommended for removals in the EE/CA. These areas do not fall within the normal Corps of Engineers OE removal categories and the normal MSD definition process would not be applicable.

However, if the removal action in the EE/CA Sector 3A or Sector 3B removal areas resulted in finding live ordnance items at the edge of the planned removal areas, the normal Corps of Engineers procedure would be to incrementally expand the removal action into the adjacent area until no further OE items are located. During the search for OE items in such an expansion area, the MSD for the MPM in the adjacent Sector A or Sector B area would continue to be used.

The MSD for sector 3A, 3B, and the expansion area would be based on a 1 Hazardous Fragment in 600 Square Feet MSD. In all these areas, a 200 feet arc would extend outward from the edge of intrusive work areas. (See map figures 1, 2, and 3)

The role of CESPK in these efforts is limited to that of providing guidance, technical reviews, site support, and advice to the City of Benicia as described in the MOA with the City of Benicia. Approval of work plans and the adoption of appropriate MSD will be up to the authorities responsible for conducting the OE removal and approving the actions.

Technical Evaluation: In Sector 3A, a 60 MM mortar has been identified as the MPM, and would have a fragmentation distance of 1080 feet. Since the munitions are not likely to be armed, it would be appropriate to a 1 Hazardous Fragment in 600 Square Feet MSD with a minimum separation distance of 200 feet.

The sector 3B area has a 37 MM projectile identified as the MPM. The 37 MM projectile has a fragmentation distance of 1181 feet. Since the munition is not likely to be armed, it would be

appropriate to a 1 Hazardous Fragment in 600 Square Feet MSD with a minimum separation distance of 200 feet.

Based on the assumption the an OE expansion protocol were needed adjacent to sector 3A or 3B, and the item located at the edge of the sector was not larger than a 60MM morter or 37MM projectile used as the MPM for the sectors, a 200 feet MSD should continued to be used for intrusive work in these areas. An appropriate MSD will need to be calculated for intentional detonations. Engineering controls can be employed during intentional detonations to reduce the blast distance.

Conclusions and Recommendations:

1. Public safety must be a leading concern for the interested parties and the Corps of Engineers in proceeding with the OE response. Public officials, public safety personnel, UXO workers, and public living and working near the site must be made aware of the hazards and responses being made to reduce them.

2. The maximum fragmentation distance calculations for the 37 MM and 60 MM MPM's (if this were a Corps of Engineers project) would be that of 1181 feet and 1080 feet, respectively. Sectors 3A and 3B would be appropriate for reduction of the MSD to a 1 Hazardous Fragment in 600 Square Feet MSD based on the MPM being unfuzed and unarmed. The reduction to a 1 Hazardous Fragment in 600 Square Feet MSD is an increased risk to the public that must be assumed by those officials approving the adoption of this reduced MSD.

3. We recommend that the public be made aware of the (MSD) and the additional hazards that they may be exposed to in the event of an unintentional detonation when using the 1 Hazardous Fragment in 600 Square Feet MSD.

4. Prior to conducting OE removal actions at this site a detailed OE Removal Work Plan will need to be developed, reviewed and approved by the appropriate agencies. The work plan will need to include a Community Safety Plan that addresses issues of public safety, coordination, notification and measures to deal with planned evacuations for both unintentional and intentional detonations. The work plan also needs to include a Contingency Action Plan to evaluate the potential for additional OE items discovered that would change the recommended MSD based on the present MPM, and for intentional detonations.

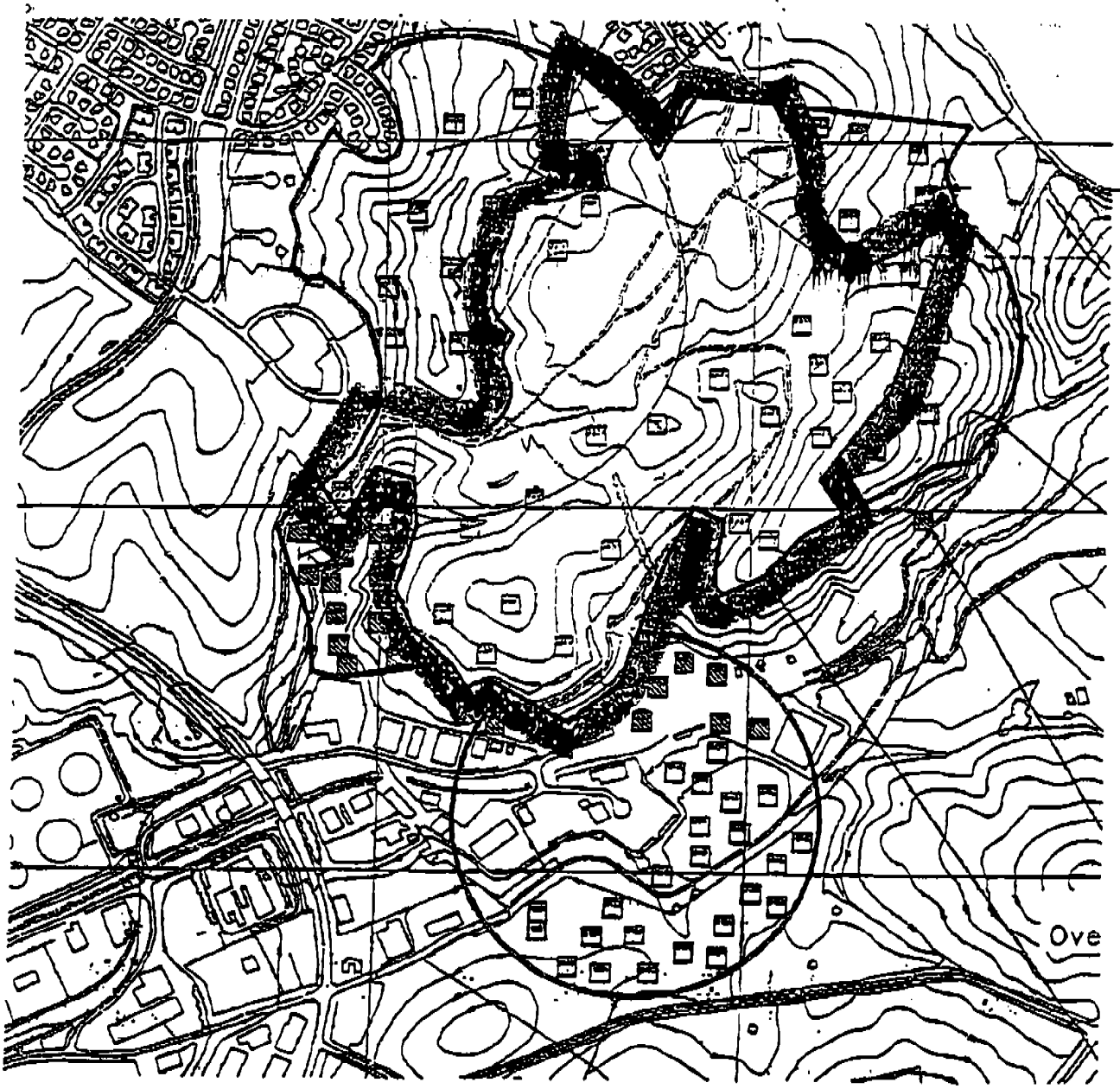
5. If at any time a UXO or a larger MPM is discovered, work must be halted and notifications be made to the appropriate authorities, who must reevaluate the MPM, MSD and the appropriateness of using a 1 Hazardous Fragment in 600 Square feet MSD. This evaluation process would establish new MSD based on the new MPM. A new evaluation and approval for a 1 Hazardous Fragment in 600 Square Feet MSD would need to be completed and be in place before any maximum fragment distance could be reduced.

FIGURE 1. Most Probable Munitions (MPM) and Minimum Separation Distance (MSD) for Sector 3A Tourtelot Property.

KEY

Intrusive Work Areas in Sector 3A.

200-foot MSD Arc around intrusive Work areas In Sector 3A. (MSD based on an unarmed 60 MM Mortar as the MPM, 1 Hazardous Fragment In 600 Sq. Ft. MSD= Arc of 200 Feet.)



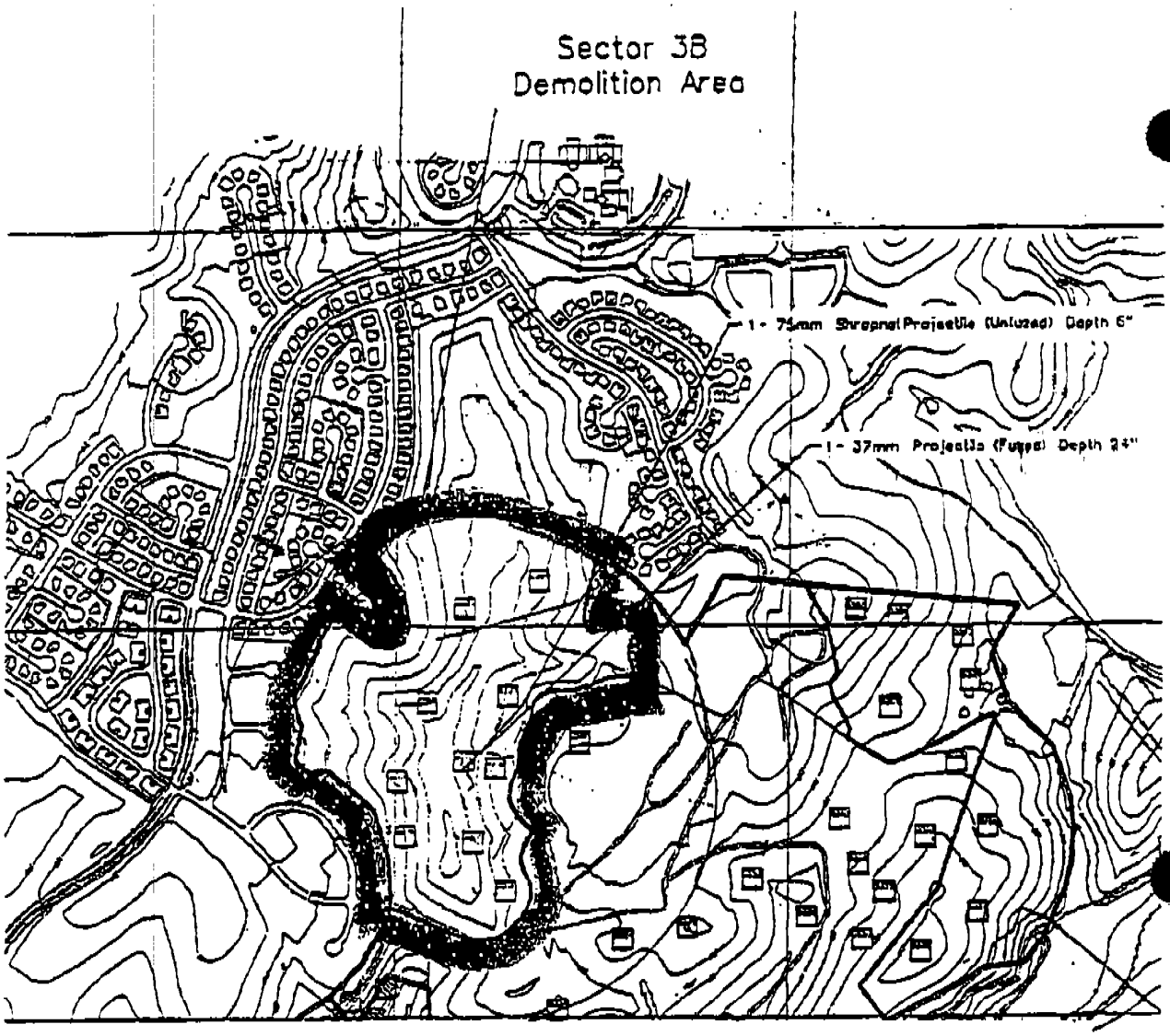


FIGURE 2. Most Probable Munitions (MPM) and Minimum Separation Distance (MSD) for Sector 3B Tourtelot Property.

KEY

Intrusive Work Areas in Sector 3B.

200-foot MSD Arc around intrusive Work areas In Sector 3B. (**MSD based on an unarmed 37 MM Projectile As The MPM, 1 Hazardous Fragment In 600 Sq. Ft. MSD= Arc of 200 Feet.**)

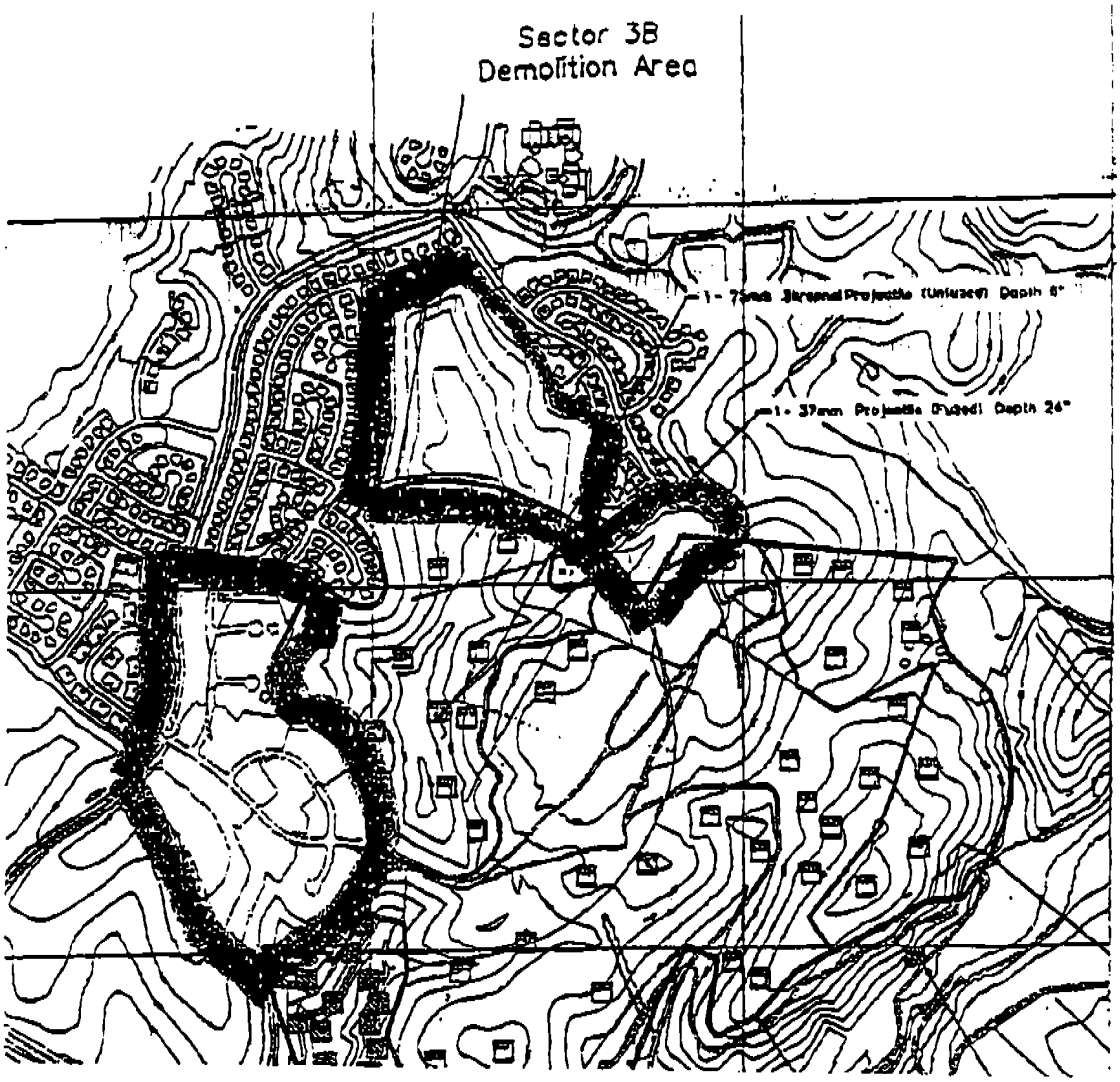


FIGURE 3. Potential Minimum Separation Distance (MSD) for OE Expansion from Sectors 3A and 3B Tourtelot Property.

KEY

Intrusive Work Areas in Potential Expansion Area Adjacent to Sectors 3A and 3B.

200-foot MSD Arc around intrusive Work areas In Expansion Area. (MSD Based Either on an Unarmed 37 MM Projectile or an Unarmed 60 MM Mortar as the MPM Extending From the Adjacent Sector, Both having the same 1 Hazardous Fragment In 600 Sq. Ft. MSD= Arc of 200 Feet.)

Department of Toxic Substances Control

Edwin F. Lowry, Director
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Winston H. Hickox
Agency Secretary
California Environmental
Protection Agency

Gray Davis
Governor

February 9, 2001

Mr. Bruce Handel
Project Coordinator
United States Army Corp of Engineers
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Sacramento, California 95814

Mr. Ted Splitter, P.E.
Project Coordinator
Northgate Environmental Management, Inc.
950 Northgate Drive, Suite 313
San Rafael, California 94903

TOURTELOT CLEANUP PROJECT ORDNANCE AND EXPLOSIVES REMEDIATION MINIMUM SEPARATION DISTANCE

Dear Mr. Handel and Mr. Splitter:

The purpose of this letter is to respond to your request to implement the United States Army Corps of Engineer (ACE) recommended Minimum Separation Distance (MSD) of 200 feet during ordnance and explosives (OE) remediation for the Tourtelot Cleanup Project. It is the Department of Toxic Substances Control's (DTSC) understanding that Granite and ACE intend to use the ACE recommended 200 foot MSD to establish an area in which all nonessential personnel will be withdrawn for their protection in the event of an accidental detonation during the OE remedial activities. Although some risk remains to the surrounding people and property, it is DTSC's understanding that Granite and the ACE are willing to appropriately address any injury or damage caused by a detonation at the site.

DTSC initially requested the use of the maximum fragmentation distance of the most probable munition as the MSD for the site. The current maximum fragmentation distance is estimated at 1,080 or 1,181 feet based on the most probable munitions to be found across the site. Granite and ACE have requested the MSD be based on the calculated distance that represents the location at which fragments in flight from an accidental detonation of the most probable munition will equal 1 hazardous fragment in a 600 square foot area (1/600). This is approximately a 1% chance for a person six feet tall and approximately one foot wide, standing in the open at the 1/600 MSD distance to be hit by a hazardous fragment in the event of an accidental detonation.

ACE has advised us that there have been no reported accidents involving clearance operations while employing the 1/600 MSD. The use of the 1/600 is not normally used for OE projects unless certain site and ordnance conditions are met. Additionally, ACE

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our Web-site at www.dtsc.ca.gov.

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goes on to state in writing that "The reduction to 1 hazardous fragment in 600 square feet MSD is a risk to the public that must be assumed by those officials approving the adoption of this reduced MSD". To date, neither Granite nor ACE have provided sufficient supporting information to allow DTSC to fully analyze the associated risk of the recommended 200 foot MSD. DTSC recognizes the ACE's experience with OE safety issues, but has concerns regarding the 1% risk. Given the above, DTSC can accept ACE's recommended 200 foot MSD, with the addition of a voluntary separation distance (VSD) encompassing the maximum fragmentation distance for the most probable munition.

DTSC believes that the OE investigation and remediation can be protective of the local community provided the following requirements are implemented and maintained throughout the course of the investigation and remediation:

1. Granite will delegate safety and quality control oversight of OE investigation, detection and remediation to ACE. All field decisions for blow-in-place or storage for destruction in a chamber will remain with the ACE.

2. ACE, in their oversight capacity, will be assured by Granite that the Minimum Separation Area Notification and Implementation Plan (MSAP) is operational and in place according to the final approved OE Remedial Design Document (RDD).

3. At a minimum, all Defense Department Explosive Safety Board recommendations and requirements will be implemented when performing OE scanning and removal of OE.

4. Properly trained ACE OE experts will be present on the project site with authority to stop work and/or modify procedures if site conditions dictate.

5. ACE will monitor all field activities to provide compliance with Quality Assurance/Quality Control plans and safety procedures. ACE will also be authorized to randomly check the OE work through appropriate means.

6. In addition to the 200 foot MSD recommended by ACE, a VSD encompassing the broader area of all residents, businesses and schools located within the maximum fragmentation distance for the most probable munition, currently 1,080 and 1,181 feet, will be notified of the potential hazards associated with an accidental detonation. The notification of all residents, businesses and schools within the VSD will include a public meeting and notification component so people can make informed decisions on the risks posed to them by this activity. Any residents, schools or businesses located within the VSD choosing to temporarily withdraw, will be offered the same support services as residents, schools and businesses located within the 200 foot MSD.

7. Both the 200 foot MSD and the VSD will be implemented at any time when OE intrusive activities are being performed. Intrusive activities include, but are not limited to, digging to identify surface and subsurface anomalies and excavation and grading activities in OE suspect areas.

8. Affected individuals within the 200 foot MSD and the VSD will be offered support services. Procedures for implementing the withdrawal will be contained in the MSAP approved by DTSC prior to the start of field work. At a minimum, the MSAP will address notification, transportation, hospitality accommodations and issues of special needs for all affected people. The MSAP will also address security for all homes and businesses of those affected individuals. Specific procedures for cost reimbursement to residents for damage caused by detonation associated with OE remediation will also be included in the MSAP as part of the final OE RDD.

9. A separate MSD will be required for handling and treatment of explosive concentrations of Trinitrotoluene (TNT) contaminated soils. To date ACE has not provided a recommended MSD. DTSC will review the proposed MSD and associated safety procedures for TNT when Granite and ACE submit the information in the OE RDD.

10. For controlled intentional detonations or controlled anomaly digs, a different MSD than the 200 foot MSD/VSD approach identified above for accidental detonations may be applied. This MSD would be based on the specific OE location, size and protective measures used for the controlled detonations or anomaly digs. The use of these types of MSDs will need to be discussed as part of the OE RDD.

If additional information or site conditions warrant changes in the above MSDs and associated activities, they may be modified upon written approval by the DTSC. My staff will be available to meet with you to discuss any questions you may have. Please feel free to contact Mr. Stewart Black at (916) 255-3712.

Sincerely,

Anthony J. Landis, P.E.
Chief
Northern California Operations
Office of Military Facilities

cc: Mr. Scott Goldie, Vice President
Pacific Bay Homes
701 Southampton Road, Suite 209
Benicia, California 94510

cc: Ms. Heather McLaughlin
City Attorney
City of Benicia
150 East L Street
Benicia, California 94510

Mr. Edwin F. Lowry, Director
Department of Toxic Substances Control
PO Box 806
Sacramento, California 95812-0806

Mr. Bob Borzelleri, Chief Deputy Director
Department of Toxic Substances Control
PO Box 806
Sacramento, California 95812-0806

Ms. Dorothy Rice, Deputy Director
Site Mitigation Program
Department of Toxic Substances Control
PO Box 806
Sacramento, California 95812-0806

Mr. Rick Moss, Chief
Permitting Division
Department of Toxic Substances Control
PO Box 806
Sacramento, California 95812-0806

To establish a minimum safe distance surrounding the TNT strips during OE operations, the "blast distance" calculated for the greatest TNT concentration hotspot detected during RI/FS sampling will be used. The blast distance is calculated using formulas provided by DoD Manual DA PAM 385-64, which considers soil volume, weight, and TNT concentration to derive an explosive weight according to:

$$\text{Blast Distance} = 40 \times (\text{soil volume} \times \text{soil weight} \times \text{percentage TNT})^{1/3}$$

For the Project Site, the maximum detected TNT concentration is 38 percent, the hotspot radius was 2 feet (as determined from the decrease in concentration in samples offset by 2 feet), the depth of the hotspot was taken as 2 feet bgs (TNT concentration at 2 feet was 11 percent, versus 38 percent a 1 foot bgs), and the soil weight was 115 pounds per cubic foot (as taken from RI/FS sampling results). The calculated blast distance (BD) then is:

$$BD = 40 \times (25.14\ ft^3 \times 115\ lb/ft^3 \times 0.38)^{1/3} = 411.78, \text{ or } 412 \text{ feet.}$$

APPENDIX H

EARTH TECH FORMS

EARTH TECH

Preparatory Phase Check List

Project Name _____ Project Number _____

Field Activity _____ Date of Activity _____ to _____

YES	NO	N/A	
____	____	____	Permits: _____
____	____	____	Applications: _____
____	____	____	Site visit performed
____	____	____	Work Plan completed, approved, distributed
____	____	____	Quality Control Plan completed, approved, distributed
____	____	____	Site-Specific Safety & Health Plan completed, approved, distributed
____	____	____	Procedure in place _____
			Personnel assigned
____	____	____	Project Manager _____
____	____	____	Site Safety Officer _____
____	____	____	Field Quality Control Manager _____
____	____	____	Other _____
			Training completed for
____	____	____	Field procedures
____	____	____	Quality control
____	____	____	Health and safety
			Equipment and supplies
____	____	____	Tested, approved
____	____	____	Calibrated
____	____	____	Field material properly stored
			Subcontractor(s): _____
____	____	____	Evaluation satisfactory
____	____	____	Procurement document/subcontract in place
____	____	____	Contaminated material holding and disposal procedures in place
____	____	____	Emergency procedures in place
____	____	____	Weather conditions accounted for
____	____	____	Review of nonconformances/audit findings completed

_____ Project Manager _____ Date

_____ Quality Control Manager _____ Date

EARTH TECH

Preparatory Phase Check List

Project Name _____ Project Number _____

Field Activity _____ Date of Activity _____ to _____

YES	NO	N/A	
			List submittals required for the work: _____
			_____
			_____
			_____
			_____
_____	_____	_____	Contract specifications reviewed
_____	_____	_____	Contract drawings reviewed
_____	_____	_____	Test procedures ready
_____	_____	_____	Activity hazard analysis conducted
_____	_____	_____	Client notified
			List any items of mutual understanding developed during the preparatory phase: _____
			_____
			_____
			_____
			List any topics of concern (i.e., safety violations observed, areas of nonconformance, etc.): _____
			_____
			_____
			_____
			_____
			List persons in attendance: _____
			_____
			_____
			_____
			_____

_____ Project Manager _____ Date _____ Quality Control Manager _____ Date

EARTH TECH GRID SURVEY ORDNANCE ACCOUNTABILITY LOG FOR OE OPERATIONS

(To be used in conjunction with OE Operations / QC Grid Map)

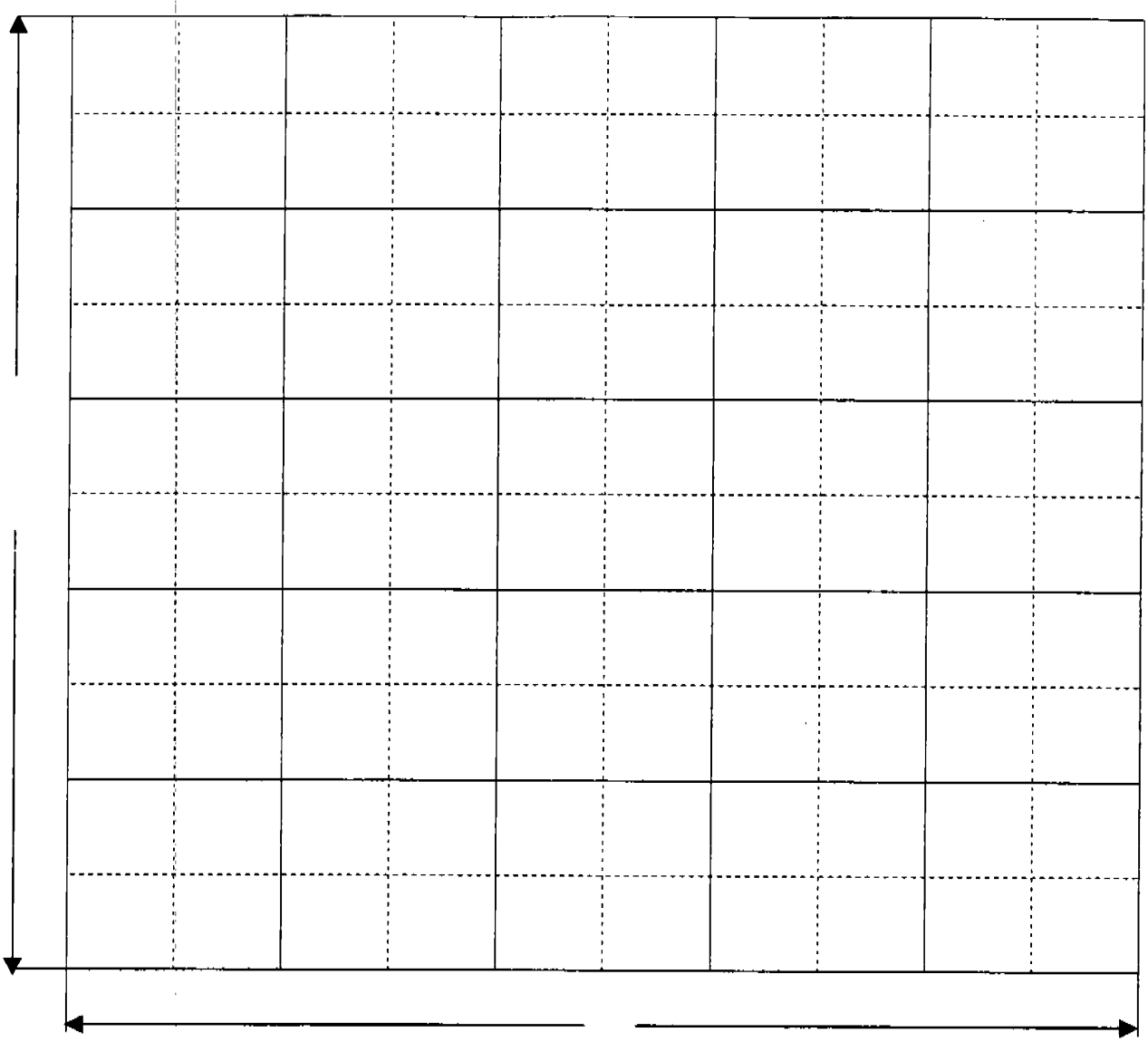
DATE:	LOCATION:	GRID NO.:	PAGE:
CONTRACT NO.:	DELIVERY ORDER NO.:	TEAM LEADER:	

Item No.	Description	No. Pieces	Fuse Type & Condition	Fill Type	Depth	Condition/State of Degradation	Comments

EARTH TECH OE OPERATIONS GRID MAP

(To be used in conjunction with Earth Tech Grid Summary Survey Log)

DATE: _____ GRID NO.: _____



NOTES: _____

_____

_____

_____

_____

_____

_____

LEGEND

Surface UXO/OE

Subsurface Anomalies

Subsurface UXO/OE

Restricted Area Boundary

Map Orientation

EARTH TECH

A Tyco INTERNATIONAL LTD COMPANY

OE Sampling Excavation Information Sheet
(Must be completed for all targets)

Sector: _____ Completed By: _____ Date: _____

Grid or Lane No: _____ UXO Supervisor: _____ Time: _____

Anomaly ID No.: _____ Crew No.: _____

TARGET DESCRIPTION

Type/Model/DOD Nomenclature: _____

☐ Unexploded Ordnance (UXO)
- ☐ Fuzed
- ☐ Unfuzed

☐ Ordnance and Explosives (OE)
☐ OE Scrap
☐ Non-OE

Primary Composition:
- ☐ Ferrous
- ☐ Aluminum
- ☐ Brass
- ☐ Other _____

Condition (Mark all that apply):
- ☐ Intact
- ☐ Partial
- ☐ Rusted
- ☐ Dented
- ☐ Other _____

Diameter: _____ mm/inches Length: _____ mm/inches Markings: _____

Weight: _____ pounds/ounces Wall Thickness _____ mm/inches Photo # _____ Camera # _____

ORIENTATION

Bearing: _____ degrees

Estimated Inclination: _____ degrees
☐ Nose Up ☐ Nose Down ☐ No Nose

Distance from Flag: _____ inches

Direction from Flag: _____ (N, S, E, W, etc.)

EXCAVATION

Method:
- ☐ Hand (Surface Debris)
- ☐ Shovel
- ☐ Backhoe

Excavation Width: _____ inches

Excavation Depth: _____ inches

Depth to Top of Item: _____ inches

DISPOSAL

☐ Blown in Place ☐ Moved to Demo Area ☐ Date of Demo _____

Comments:

_____

_____

_____

_____

UXO Supervisor review by: _____ Title: _____ Date: _____

Earth Tech review by: _____ Title: _____ Date: _____

NOTE: USE MULTIPLE SHEETS FOR MULTIPLE ITEMS.

EARTH TECH DEMOLITION SHOT RECORD

Site Name/Location:		Date:
Shot Location (OB/OD Range or Grid No.):	Demolition Supervisor:	State License # (if applicable):
Type of UXO/OE Destroyed, Vented, or Burned:	Firing Method:	Time of Shot:
Direction and Distance to Nearest Building, Road, Utility Line, etc.:	Temp: _____ Wind Dir./Speed: _____ Ceiling: _____ Clouds/$ Sun: _____	
Type and Amount of Tamping Used:		Mat or Other Protection Used (list):
Seismographic/Sound Level Meter Used: Yes ☐ No ☐	Readings/Results:	

Demolition Materials Used

Description	Amount	Description	Amount
Perforator		Time Fuze	
Det Cord		Squibs	
Electric Detonator		Black/Smokeless Powder	
Non-Electric Detonator		Two Component	
Non-El Detonator		Other (list)	

Certification

I certify that the explosives listed were used for their intended purpose, and that the UXO/OE listed were rendered inert/destroyed.

Signature of Demolition Supervisor: _____ Date: _____

Site Name/Location:		Date:
Shot Location (OB/OD Range or Grid No.):	Demolition Supervisor:	State License # (if applicable):
Type of UXO/OE Destroyed, Vented, or Burned:	Firing Method:	Time of Shot:
Direction and Distance to Nearest Building, Road, Utility Line, etc.:	Temp: _____ Wind Dir./Speed: _____ Ceiling: _____ Clouds/% Sun: _____	
Type and Amount of Tamping Used:		Mat or Other Protection Used (list):
Seismographic / Sound Level Meter Used: Yes ☐ No ☐	Readings/Results:	

Demolition Materials Used

Description	Amount	Description	Amount
Perforator		Time Fuze	
Det Cord		Squibs	
Electric Detonator		Black/Smokeless Powder	
Non-electric Detonator		Two Component	
Non-El Detonator		Other (list)	

Certification

I certify that the explosives listed were used for their intended purpose, and that the UXO/OE listed were rendered inert/destroyed.

Signature of Demolition Supervisor: _____ Date: _____

EARTH TECH UXO QUALITY CONTROL INSPECTION AND AUDIT LOG

FOR OE OPERATIONS

DATE:	TIME	LOG NO.
CONTRACT NO.:	DELIVERY ORDER NO.:	

LOCATION:

WEATHER CONDITIONS:

I. AREAS INSPECTED: (List by grid number, coordinates or description)

II. INSPECTION RESULTS:

III. CORRECTIVE ACTIONS RECOMMENDED (If required):

IV. REINSPECTION RESULTS (If required):

V. SIGNATURES:

I acknowledge that I have been briefed on the results of this inspection and will take corrective actions (if necessary).

Quality Control Specialist

Sr. UXO Supervisor / Project Manager

EARTH TECH EXPLOSIVE ACCOUNTABILITY RECORD
(Magazine Data Card)

Product Code/FSN		Nomenclature		Location		
Date Code/Lot NR		NR Package/Case		NR Cases		
Date	Bill Lading/Voucher NR	Rcvd. From/Issued To	Qty. Received	Qty. Issued	Balance	Initials
/ /						
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EARTH TECH EXPLOSIVES PURCHASE/RECEIPT/TRANSPORTATION
AUTHORIZATION LIST

Address and County (Home Office): 1461 East Cooley Drive, Suite 100, Colton, CA 92324, San Bernardino County

Address and County: (Field Office)

Federal License #: Expiration Date:

The following persons are agents, employees, or representatives of the undersigned, and are authorized to order or acquire explosive materials on behalf of EARTH TECH, INC.:

Name and Home Address	Driver's License No.	Soc. Sec. Number	Place of Birth

The undersigned certifies the foregoing information to be true and correct to the best of his knowledge and believe, and that he will communicate any additions or deletions to the foregoing list to Earth Tech, Inc.

Corporate Officer	Date

EARTH TECH

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Team # _____

EARTH TECH VEHICLE INSPECTION CHECKLIST

(To be used weekly for all vehicles EXCEPT explosive carriers which must be inspected prior to each explosives transport)

Site Name / Location: _____

SUXOS: _____ Inspector: _____ Vehicle: _____
(MAKE & LICENSE PLATE #)

Date Inspected: _____ Mileage: _____ Owner: _____
(RENTAL, EODT, GFE, CONTRACT)

USE ô FOR PASS, X FOR DISCREPANCY

1. DOCUMENTATION:	Pass	Fail	2. BRAKES:	Pass	Fail
Registration	[ ]	[ ]	Hand/Emergency	[ ]	[ ]
Insurance	[ ]	[ ]	Service	[ ]	[ ]
Emergency Route Map and Phone Numbers	[ ]	[ ]			
3. TIRES:			**4. BELTS:**		
Pressure	[ ]	[ ]	Proper tension	[ ]	[ ]
Condition	[ ]	[ ]	Condition	[ ]	[ ]
5. EQUIPMENT:			**6. LIGHTS:**		
Fire extinguishers*	[ ]	[ ]	Headlights (high & low)	[ ]	[ ]
First Aid/CPR/Burn	[ ]	[ ]	Brake Lights	[ ]	[ ]
Eyewash kits	[ ]	[ ]	Parking	[ ]	[ ]
Emergency Breakdown Kit	[ ]	[ ]	Back-up	[ ]	[ ]
Spare Tire	[ ]	[ ]	Turn Signals	[ ]	[ ]
Tire Changing Equipment	[ ]	[ ]	Emergency Flashers	[ ]	[ ]
Tie downs*	[ ]	[ ]			
Chocks*	[ ]	[ ]			
Placards*	[ ]	[ ]			
7. FLUID LEVELS:			**8. GENERAL:**		
Oil	[ ]	[ ]	Windshield Wipers	[ ]	[ ]
Coolant	[ ]	[ ]	Windshield/Windows	[ ]	[ ]
Brake	[ ]	[ ]	Seat Belts	[ ]	[ ]
Steering	[ ]	[ ]	Steering	[ ]	[ ]
Transmission	[ ]	[ ]	Horn	[ ]	[ ]
Windshield Wiper	[ ]	[ ]	Gas Cap	[ ]	[ ]
Fluid Leaks	[ ]	[ ]	Mirrors	[ ]	[ ]
			Cleanliness	[ ]	[ ]
			Exhaust system*	[ ]	[ ]

(Note: Items marked with * are required for explosive carriers and must be inspected prior to each use)

Description of deficiencies: _____

_____

_____

Deficiencies corrected by: _____ Date _____

EARTH TECH

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EARTH TECH DAILY EQUIPMENT STANDARDIZATION/RESPONSE CHECK LOG

Location:	Contract No.:	Delivery Order No.:	QCS:

Geophysical Equipment Nomenclature	Serial Number	Standardization / Response Check Test Date for Week Ending _____							Comments
		SUN	MON	TUE	WED	THUR	FRI	SAT	
		Initials of Person Conducting Standardization / Response Check							

GPS Equipment Nomenclature	Serial Number	Standardization / Response Check Test Date for Week Ending _____							Comments
		SUN	MON	TUE	WED	THUR	FRI	SAT	
		Initials of Person Conducting Standardization / Response Check							

Earth Tech, Inc.
Tailgate Safety Briefing Sign-in Log
Date: Time:

Briefing Conducted By:	Signature:	Company Name:

This sign-in log documents the tailgate safety briefing conducted in accordance with 29 CFR 1910.120 "Hazardous Waste Operations and Emergency Response" as well as other applicable regulatory requirements. Personnel who perform work operations onsite are required to attend each safety briefing and acknowledge receipt of such briefings daily.

TOPICS COVERED:		
☐ General PPE usage	☐ Decontamination Procedures	☐ Existing Work Zones
☐ Hearing Conservation	☐ Smoking, Eating, and Drinking	☐ Lockout/Tagout Safety
☐ Respiratory Protection	☐ Slips, Trips, and Falls	☐ Excavation/Confined Space Safety
☐ Personal Hygiene	☐ Heat Stress	☐ New Work Procedures
☐ Exposure Guidelines	☐ Site Control	
	☐ Emergency Procedures	

Personnel Sign-in List

Printed Name	Signature	Company Name

Supervisor's Report of Incident

EARTH TECH
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This is an official document to be initiated by the injured employee's Supervisor. Please answer all questions completely. Fax to your Region's EHS Manager within 24 hours of the injury. See reverse side for instructions.

Section 1: Employee (Must complete each item or processing delays will occur) - Print Clearly

SCMS Claim#: _____ WC Location Code: _____

SCMS: (877)261-8926

Employee Data	S.S. No.	Sex	Birth Date
Injured's Name	Home Phone	Marital Status	No. Dependents
Home Address	City	State	Zip Code
Job Title / Dept No.	Office Location/Address		
☐ Injury ☐ Illness ☐ Vehicle Injury ☐ Near Miss		Hire Date	Hourly Wage

Section 2: Supervisor (Must complete each item or processing delays will occur) - Print Clearly

Date of Incident	Time	Date Reported	To Whom
Client Name	Job Assignment at Time of Incident		Time Shift Began
Exact Location & Address of Incident		Did injured leave work? ☐ Yes ☐ No When?	
Has injured returned to work? ☐ Yes ☐ No		Did employee miss a regularly scheduled shift? ☐ Yes ☐ No	
Doctor/Hospital Name		Address of Hosp.	
Witness Name		Statements Attached ☐ Yes ☐ No	
Nature of Injury		Body Part	
Medical Treatment Received			
Describe Incident			
What caused the incident?			
Corrective Action(s) to Prevent Future Occurrence:			
Supervisor/Foreman (Print Name)	Signature	Date	Telephone

Section 3: Manager

Comments on incident and corrective action			
Manager (Print Name)	Signature	Date	Telephone

Section 4: Environmental, Health and Safety

Concur with action taken? ☐ Yes ☐ No Remarks:			
OSHA Recordable ☐ No ☐ Pending ☐ Yes - Type : ☐ Incident only ☐ First aid ☐ Medical ☐ Fatality Lost work days _____ Days of restricted activity _____			
EHS Professional (Print Name)	Signature	Date	Telephone

This report contains information protected by the Privacy Act

Supervisor's Report of Incident
Instructions For Completion

The following types of incidents must be reported using this form:

1. Occupational Injury or Illness (includes first aid only, medical treatment, hospitalization, fatality)
2. Vehicle Accident Injuries
3. Near Miss (incident where employee(s) could have been injured)

INSTRUCTIONS

Immediate:

1. Employees must report such incidents to their Supervisor **immediately**.
2. The Supervisor must complete **Sections 1 and 2, Employee Data and the Supervisor Section** of the SRI. Incomplete items will delay timely processing. Any work-related injury or illness that requires medical treatment or care will require notifying SCMS at 877-261-8926.
3. The Supervisor must verbally notify his/her Manager, who in turn must sign **Section 3, Manager**, of the SRI. To avoid delaying SRI process, a separate copy of the SRI with the Manager's signature can be faxed within 3 days to the REHSM.
4. The Supervisor must verbally notify his/her REHSM with a follow-up SRI faxed within 24 hours (see below for fax numbers). The REHSM will review and complete **Section 4, Environmental Health and Safety,** and fax the SRI to the WCA at 804-515-8313.
5. For near-miss situations that could have resulted in an injury to an employee, the Supervisor must notify his/her Manager (see Item 3 above) and the REHSM with a follow-up SRI faxed within 24 hours.

PRIMARY CONTACTS

East REHSM: Dale Prokopchak, CIH, CSP
Telephone: 804-515-8556
Fax: 804-515-8313
Pager: 877-830-1981

WCA:
Telephone: 804-515-8557
Fax: 804-515-8313

Midwest REHSM: Jeff Grant, CIH
Telephone: 616-940-4426
Fax: 616-940-4396
Cell Phone: 734-516-5232

West REHSM: Bob Poll, CIH, CSP
Telephone: 562-951-2242
Fax: 562-495-9257
Cell Phone: 562-884-1414

This report contains information protected by the Privacy Act.

Daily Quality Control Report

Location:	Contract Number:	Date:
Weather: (Clear) (P. Cloudy) (Cloudy) Rainfall: _____ inches	Temperature: (Fahrenheit) Current ____ Low ____ High ____	

1) Contractor/Subcontractor Personnel	Area of Responsibility
a)	
b)	
c)	
d)	
e)	
f)	
g)	
h)	
i)	
j)	
k)	
l)	
m)	
n)	
o)	
p)	
q)	
r)	
s)	
t)	

2) Work performed today (Indicate location, description, and personnel performing work).

3) Results of safety inspection (Indicate what was checked, results, and corrective actions if applicable. Note phase of work where any violations occurred.)

EARTH TECH
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Daily Quality Control Report

4) Indicate test and/or control activities performed with results and references to the OE RDD requirements (note deficiencies and corrective actions).

5) Verification of equipment inspections (note any inspection failures and corrective actions).

a) Vehicles:

b) Geophysical equipment:

c) GPS equipment:

d) Miscellaneous:

6) Materials delivered to the site:

Earth Tech verification: The above report is complete and correct and all material and equipment used and work performed during the reporting period are in compliance with the contract plans and specifications except as noted above.

Earth Tech Approved/Authorized Representative

EARTH TECH

Quality Deficiency Notice

(Part I)

QDN Number _____

Project Name _____ Project Number _____

Activity _____ Location _____

Controlling Document:

Requirement

Description of Deficiency

Reported by _____ Date _____

Discussed with _____ Date _____

Response

This section to be completed by responsible organization and returned to the Earth Tech QC Manager or designated representative by _____ (Date).

Corrective Action (including action to prevent recurrence and root cause determination)

Scheduled Completion Date _____ Signed _____ Date _____

EARTH TECH

Quality Deficiency Notice

(Part II)

Evaluation of Response QDN Number _____

This section to be completed by the Quality Control Manager		
First Response	☐ Satisfactory	☐ Unsatisfactory
Remarks		
Evaluated by _____	Date _____	
Second Response	☐ Satisfactory	☐ Unsatisfactory
Remarks		
Evaluated by _____	Date _____	
Third Response	☐ Satisfactory	☐ Unsatisfactory
Remarks		
Evaluated by _____	Date _____	
Corrective action verified	☐ Yes	☐ N/A
Remarks		
Verified by _____	Date _____	
Quality deficiency notice closed on _____	By _____	

EARTH TECH

Nonconformance Report (NCR)

NCR No. ____

Project _____ Project Number _____

Activity _____ Location _____

Part A

Description of nonconformance

Nonconformance reported by _____ Date _____

Part B

Evaluation of nonconformance

Significant condition adverse to quality ☐ Yes ☐ No

Work stoppage required ☐ Yes ☐ No

Impacts previous data/reports ☐ Yes ☐ No

Remarks:

Evaluated by _____ Date _____ Title _____

Approved by _____ Date _____ _____ Date ____
Project Manager QC Manager

Part C

Recommended corrective action/disposition

Evaluated by _____ Date _____ Title _____

Approved by _____ Date _____ _____ Date ____
Project Manager QC Manager

Part D

Corrective action/disposition

Completed by _____ Date _____

Remarks:

Corrective action approved and NCR closed by:

_____ Date _____ _____ Date _____
Project Manager QC Manager

EARTH TECH

Nonconformance Report Log

NCR No.	Project/Activity	Date initiated (Part A)	Date NCR closed (Part D)	Remarks

EARTH TECH

DELIVERABLE REVIEW AND APPROVAL

FORM Q-1

Project Name:	
Project Number:	Certification Required:

Peer Review Assignments	
Reviewer: Date Comments Required: NTE _____ Hours Special Emphasis:	☐ Technical ☐ Editorial ☐ Statement of Work Compliance
Reviewer: Date Comments Required: NTE _____ Hours Special Emphasis:	☐ Technical ☐ Editorial ☐ Statement of Work Compliance
Reviewer: Date Comments Required: NTE _____ Hours Special Emphasis:	☐ Technical ☐ Editorial ☐ Statement of Work Compliance

PEER REVIEW SCHEDULE

Date	Event

Project Manager Signature:	Date:

EARTH TECH

DELIVERABLE REVIEW AND APPROVAL

FORM Q-2

PEER REVIEW	
Document Title:	
Document Date:	Project Number:
Peer Reviewer's Name:	
Date Comments Required: NTE _____ Hours Special Emphasis:	
I have reviewed this document for: ☐ Technical Quality ☐ Conformance to Scope ☐ Editorial Quality	This review resulted in: ☐ No Comments ☐ Minor or Editorial Comments ☐ Significant Comments
☐ Document markup attached	☐ Supplemental comments attached
Signature:	Date Received: Date Completed:

RESPONSE TO PEER REVIEW COMMENTS	
Responses Prepared By:	
Peer review comments have been ☐ incorporated without exception ☐ incorporated with exception(s). Any exceptions must be explained in a written attachment.	
Signature:	Date:

MANAGEMENT APPROVAL	
Project Manager:	Date:
Office Manager:	Date:

EARTH TECH

NONCONFORMANCE REPORT

Page ___ of ___

FORM Q-3

Project Name:
Project Number:

DESCRIPTION OF NONCONFORMANCE	
☐ Peer Review Plan (Form Q-1) ☐ Deliverable Review and Approval (Form Q-2) ☐ Peer Review Procedures	
Description:	
Prepared By:	Date:

PROJECT MANAGER RESPONSE	
Project Manager Signature:	Date:

QC MANAGER APPROVAL	
QC Manager Signature:	Date:

EARTH TECH

Controlled Document Transmittal Record

To: _____

_____

_____

_____ Date _____

☐ QA program manual for _____

☐ Calibration / service specification manual

☐ Procedure No. _____ Procedure name _____

☐ Work plan for project No. _____ Title _____

Revision No. _____ or revision date _____

Control No. _____

Instructions / remarks / variances

Please sign below and return to:

☐ I acknowledge receipt of the above document

☐ I acknowledge receipt of the revision to the above document and I have destroyed / marked the superceded version

☐ I am returning the document with this transmittal record

Signature _____ Date _____

EARTH TECH

Field Change Request

Field Change No. ____

Page ____ of ____

Project Name _____

Contract Number _____ Project Number _____

Applicable Document _____ Date _____

DESCRIPTION

Minor Change ☐ Major Change ☐ Major Project Impact ☐

Requested by _____

REASON FOR CHANGE

RECOMMENDED DISPOSITION

IMPACT ON PRESENT AND COMPLETED WORK

Cost Impact _____

Accepted ☐ Rejected ☐ Signature _____ Date _____
Project Manager

Accepted ☐ Rejected ☐ Signature _____ Date _____
Project QC Manager

(For changes to engineering drawings and construction specifications)

Accepted ☐ Rejected ☐ Rework ☐ Signature _____ Date _____
Responsible Engineer

Remarks:

FINAL DISPOSITION

Signature _____ Date _____

EARTH TECH

Field Change Request Log

Project Name _____

Contract Number _____ Project Number _____

Field Change Request No.	Level of Change*	Activity	Date initiated	Final Disposition	Remarks

* Min C = Minor Change
Maj C = Major Change
MPI = Major Project Impact

EARTH TECH

Audit Status

Program / Project _____

Audit Number	Audit Subject	Date of Audit	Date of Audit Report	Quality Deficiency Notices				Audit Closed Date
				Number	Responses		Closed	
					Due	Received		

PROJECT CONFORMANCE AUDIT SCHEDULE

PROJECT:
AUDIT/INSPECTION DATE:

QA/QC CHECK LIST

CHECK	SCH	REFERENCE	YES	NO	N/A	COMMENTS
A. Review OE RDD						
1. Clearance area and objectives clearly identified.	A	OE RDD Section 1.1				
2. All modifications and changes added and up to date.	M					
3. Work plan current and all changes posted.	M					
4. Depth of clearance identified.	S	OE RDD Section 4.8				
5. Minimum Separation Distance (MSD) established based on the Most Probable Munition (MPM).	S	OE RDD Section 3.3				
6. Proper target OE identified and test sources/test plot established.	A	OE RDD Sec. 4.7, 4.8, 4.9, 4.10				
7. Maps identifying the proper MSD located in the OE RDD for each clearance area.	A	OE RDD Sec 3.0 and 4.0				
8. Standards for the turn-in of OE scrap from the OE RDD.	A	DOD 4160.21 M 1				
9. Copy of the Explosive Safety Submission (ESS) at the Project Site.	A	DDESB IGD 98 10 Ch. 10				
B. Documentation Requirements on Site:	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
DTSC Order						
1. RI/FS	A					
2. EIR	A					
3. RAP	A					
4. OE/RDD	A					
5. Non-OE RDD	A					
6. ESS	A					
7. SSHP, Addendum 1 and 2	A					
8. Letter authorizing project start-up.	A					

QA/QC CHECK LIST

9. USACE UXO personnel approval letter for all UXO personnel on site.	A					
10. Department of Defense Notice to Airmen (NOTAM) FWD to the area Federal Aviation Administration	A	AR 95 10, CFR 11 208				
11. Contract and all modifications and change orders.	M					
12. Approval letter for MSD, 1 Frag in 600 sq. ft.	A	OE RDD Appendix D				
13. First Aid and CPR training certificate (required to have a minimum of two qualified personnel on site when field activities are taking place).	M	EM 385 1, Sec. 03.A.02				
14. File on all UXO qualified personnel to include: NAVSCOLEOD cert., up to date physical, 40-hr HAZWOPER cert., up to date 8-hr HAZWOPER cert.	M	29 CFR 1910.120 (f)(e)				
15. File on SUXOS, QC, SSO, and all UXOSs, a copy of an 8-hr HAZWOPER supervisor cert.	M	29 CFR 1910.120 (f)(e)				
16. QA/QC files established.	M	OE RDD Sec. 3.5				
17. Daily Field logs established for all on-site supervisors and above, and maintained as project property and reviewed daily by the site manager or his representative.	A	OE RDD Sec. 4.0				
C. Safety Requirements:	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. Hazard Analysis and Risk Assessment for all project tasks and on-site equipment.	A	**DID OT 005 06**				
2. Personnel protective equipment (PPE) for all on-site personnel to include visitors.	M	EM 385 1 1, 29 CFR 1910.120/134, OE SSHP (OE RDD Appendix E)				
3. First-aid equipment immediately available to all on-site personnel.	M	EM 385 1 1				
4. Emergency eye wash immediately available to all on-site personnel.	M	ANSI 385.1				
5. Fire extinguishers posted as required in all on-site vehicles, and in all on-site buildings.	M	DID OT 005 06, EM 385 1 1				

QA/QC CHECK LIST

6. Ongoing Safety and Health (S&H) Training Program.	M	OE SSHP (OE RDD Appendix E)				
7. Emergency Notification List (ENL) posted and available to all on-site personnel.	M	DID OT 005 06 OE SSHP (OE RDD Appendix E)				
8. Emergency Route Maps provided to all on-site personnel.	M	DID OT 005 06 OE SSHP (OE RDD Appendix E)				
9. Work task identified in Hazardous Analysis.	A	DID OT 005 06 OE SSHP (OE RDD Appendix E)				
10. Copies of MSDSs for all hazardous substances used and/or stored on site.	M	DID OT 005 06				
D. Facilities:	**SCH**	**EM 385 1 1**	**YES**	**NO**	**N/A**	**COMMENTS**
1. Adequate work space and restroom facilities.	M					
2. Good housekeeping maintained.	D					
3. Approved containers for flammable storage used.	W					
4. Approved explosive storage facilities used on site.	W					
5. Fire exits marked and not blocked.	D					
6. Maximum personnel occupancy limits maintained at on-site office facilities.	D					
E. Equipment	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. Tools adequate and serviceable.	W					
2. PPE adequate and serviceable and used.	D					
3. Equipment calibrated and tested.	M					
4. GPS systems inspected and serviceable.	W					
5. Geophysical equipment on site inspected, tested, serviceable, and identified in the OE RDD.	W					
6. Demolition equipment inspected and serviceable.	D					
7. Two separate means of on-site communications inspected and serviceable.	W					

QA/QC CHECK LIST

8. Heavy equipment inspected and serviceable.	D					
9. Hand and power tools inspected and serviceable.	W					
F. Transportation of Explosive Materials	**SCH**	**DOT 49 CFR Parts 100 to 199, AR 385 64, EM 385 1 1 Sec. 29**	**YES**	**NO**	**N/A**	**COMMENTS**
1. Motor vehicle inspection performed.	D					
2. Vehicles transporting explosives display all required placards, lettering, and numbers required.	D					
3. Compatibility requirements maintained.	D					
4. Load blocked and braced.	D					
5. First-aid kit and 2 10 lb. Fire extinguishers rated for BC fires maintained in the vehicle.	D					
6. Vehicle communications inspected and serviceable.	D					
7. Operators conducting transport have a valid driver's license and current CDL.	D					
8. No flame-producing articles in transport vehicle or on persons conducting transport, or handling the explosives.	D					
G. Explosives Management Plan:	**SCH**	**ATF 5400.7, DOT REG., AR 190 11, DID OT 005 03**	**YES**	**NO**	**N/A**	**COMMENTS**
1. Licenses and permits as required.	A	OE RDD Sec. 4.17				
2. Proper magazine type used.	A	OE RDD Sec. 4.17				
3. Explosive Acquisition Plan in place before starting field operations.	A	OE RDD Sec. 4.17				
4. Explosive compatibility maintained.	W	OE RDD Sec. 4.17				
5. Initial receipt procedures and documentation procedures on site and followed.	M	OE RDD Sec. 4.17				
6. Fire-fighting control plan established and posted.	A					
7. Proper fire division symbol at entrance to storage site.	A					

QA/QC CHECK LIST

8. Area around magazine free of rubbish, brush, dry grass, trees, for a minimum of 25 feet.	M					
9. Physical security and key control plan in place.	A					
10. Magazine site meets all BATF, state, and local requirements	A					
11. Magazine NEW is maintained at or below the established weight at all times.	W	OE RDD Sec. 4.17				
12. Receipt procedures accounting for each explosive item received have been established.	A	OE RDD Sec. 4.17				
13. A list of persons authorized to receive, issue and transport explosives will be maintained on-site.	M					
14. End user is certifying use in writing.	W					
15. Explosives inventory conducted weekly.	W					
16. Magazine Data Cards maintained.	W	OE RDD Sec. 4.17				
H. GIS System	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. Utilization of standardized naming conventions.	D	OE RDD Sec. 3.5, 4.18				
2. Records of activities performed on the project data maintained.	D	OE RDD Sec. 4.18				
3. Records of metadata maintained.	D	OE RDD Sec. 4.18				
4. Performance of regular (daily/weekly) data backups.	D/W					
5. Transmission of data to Granite/USACE/DTSC.	TBD					
I. Quality Control Plan	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. QC audits/inspections completed, and recorded as required.	M	OE RDD Sec. 6.5				
2. QC training conducted as required.	M	OE RDD Ch. 6.0				
3. Results of QC checks being properly recorded.	M	OE RDD Sec. 4.18				
J. Vegetation Removal	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**

QA/QC CHECK LIST

1. Equipment operated to prevent impact with OE.	D	OE RDD Sec. 4.3				
2. UXO personnel monitoring removal operation.	D	OE RDD Sec. 4.3				
3. If OE is discovered it is marked and handled appropriately.	D	OE RDD Sec. 4.3				
4. Vegetation cleared IAW site work plan.	D	OE RDD Sec. 4.3				
K. Survey and Mapping	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. OE escort provided.	D	OE RDD Ch. 4.0, para 4.6				
2. Grid stake locations checked by the OE escort with geophysical equipment prior to driving stakes.	D	OE RDD Ch. 4.0, para 4.6				
3. Grids marked IAW site work plan.	W	OE RDD Ch. 4.0, para 4.6				
4. Grids documented IAW site work plan.		OE RDD Ch. 4.0, para 4.6				
L. OE Surface Clearance	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. Operation being conducted IAW site work plan.	D	OE RDD Sec. 4.7				
2. SUXOS on site during all field operations.	D	OE RDD Sec. 4.7				
3. SUXOS, UXOSSO, UXOQC, and UXOS maintaining proper field logs.	W	OE RDD Sec. 4.7				
4. MSD established prior to conducting OE operations.	D	OE RDD Sec. 4.7				
5. UXOS conducted and documented Tailgate Safety Brief prior to starting work.	W	OE RDD Ch. 4.1, SSHP				
6. PPE being provided and used properly on site.	D	OE RDD Ch. 4.0, SSHP				
7. OE scrap and metallic debris larger that 1" by 2" removed and placed in the SW corner of the grid.	W	OE RDD Sec. 4.7				
8. All OE and OE scrap were processed IAW the OE Process Flowchart, and procedures established in the OE RDD.	W	OE RDD Sec. 4.10				
M. Location Surveys	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**

QA/QC CHECK LIST

1. Location and surveys were conducted IAW the site work plan.	A	OE RDD Sec. 4.6, 4.10				
2. "Class 1, Third Order" or better used to established for the network monuments.	A	OE RDD Sec. 4.6, 4.10				
3. Control points identified on a map by name and number.	A	OE RDD Sec. 4.6, 4.10				
N. Geophysical Systems/Operations	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. Review of daily field QA documentation.	W	OE RDD Sec. 4.8, 4.9				
2. Review of standardization logs.	D	OE RDD Sec. 4.9.1				
3. Posting of data for each segment to GIS map.	D	OE RDD Sec. 4.9.2				
4. Contour/image/profile plots generated..	D	OE RDD Sec. 4.9				
5. Comparison of field anomaly map, digital data image, and OE sampling results for each grid.	W	OE RDD Sec. 4.9.2				
O. Anomaly Reacquisition	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. OE escort provided.	D					
2. Relocate with at least 40-cm accuracy.	D	OE RDD 4.10				
P. OE Subsurface clearance and Disposal	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. MSD established based on the MPM.		OE RDD Sec. 3.0				
2. Near-surface anomalies are being excavated using hand tools.	D	OE RDD Sec. 4.10				
3. Hand-held metal detector used to check and verify the location of the anomaly being excavated.	D	OE RDD Sec. 4.10				
4. Prior to surface clearance when heavy equipment is used to excavate subsurface anomalies, the entrance and egress path is cleared and marked prior to its arrival.	S	OE RDD Sec. 4.7				
5. Heavy equipment is used IAW the procedures established in the site work plan.	S	SSHP and Addendum 2				

6. OE identification and disposal conducted by the Disposal Operations Team.	S	OE RDD Sec. 4.11				
7. Area wide clearance.	D	OE RDD Sec. 4.14				
8. Cut and fills visually observed by UXO personnel.	D	OE RDD Sec. 4.14				
9. Are OE items being properly identified?	S	OE RDD Sec. 4.10				
10. Is determination of safe to move being made IAW the on-site work plan?	S	OE RDD Sec. 4.10				
11. Is OE disposal being conducted IAW the on-site work plan?	S	OE RDD Sec. 4.11				
12. Are all demolition operations being conducted IAW USACE approved procedures?	S	OE RDD Sec. 4.11				
13. Is the OE Disposal Operations Team organized IAW the on-site work plan?	S	OE RDD Sec. 4.11				
14. OE demolition site selected and prepared prior to the start of field operations.	A	OE RDD Sec. 4.11				
Q. OE Scrap Disposal			**YES**	**NO**	**N/A**	**COMMENTS**
1. Removal and disposal of OE scrap conducted IAW the on-site work plan.	S	OE RDD Sec. 4.11				
R. Explosive Soils Operations (TNT Strips)			**YES**	**NO**	**N/A**	**COMMENTS**
1. TNT Strip operations conducted IAW on-site work plan.	D	OE RDD Sec. 4.12				
b. Homogenization operations conducted IAW on-site work plan.	D	OE RDD Sec. 4.12				
c. Field confirmation sampling conducted IAW on-site work plan.	S	OE RDD Sec 4.12				
d. Supplemental worker protection provided.	D	OE RDD Sec. 4.12				
S. Project Close Out	**SCH**		**YES**	**NO**	**N/A**	**COMMENTS**
1. All after-action activities conducted as indicated by the project schedule.	S	OE RDD Appendix A				

QA/QC CHECK LIST

A = annual (or once at the start of a project)
D = daily
M = monthly
S = situational (as required)
TBD = to be determined
W = weekly

APPENDIX I

STANDARD OPERATIONS PROCEDURES
DEMOLITION/DISPOSAL OPERATIONS

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APPENDIX I
STANDARD OPERATING PROCEDURES
OE OPERATIONS - DEMOLITION/DISPOSAL OPERATIONS

1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide the minimum procedures and safety and health requirements applicable to the conduct of demolition/disposal operations on sites contaminated with ordnance and explosives (OE). If procedures in this SOP conflict with procedures or guidelines in the OE SSHP and OE RDD, the more stringent requirement will be applied.

2.0 SCOPE

This SOP applies to all site personnel, including contractor and subcontractor personnel, involved in the conduct of OE demolition/disposal operations on an OE contaminated site. This SOP is not intended to contain all of the requirements needed to ensure complete compliance, and should be used in conjunction with project plans and applicable federal, state, and local regulations.

3.0 REGULATORY REFERENCES

Applicable sections and paragraphs in the documents listed below will be used as references for the conduct of OE demolition/disposal operations:

- OSHA General Industry Standards, 29 CFR 1910
- OSHA Construction Standards, 29 CFR 1926
- CEHNC Safety Concepts and Basic Considerations for Unexploded Ordnance
- USACE EM 385-1-1, Safety and Health Requirements Manual
- DOD 4145.26-M, Contractor's Safety Manual for Ammunition and Explosives
- DOD 4160.21-M, Defense Reutilization and Marketing Manual
- DOD 6055.9-STD, DOD Ammunition and Explosives Safety Standards
- AR 385-64, Ammunition and Explosive Safety
- AR 385-10, Army Safety Program
- DA PAM 385-64, Ammunition and Explosives Safety Standards
- TM 9-1300-206, Ammunition and Explosive Standards
- TM 9-1300-200, Ammunition General
- TM 9-1300-214, Military Explosives
- TM 60A-1-1-31, EOD Disposal Procedures
- AR 190-11, Physical Security of Arms, Ammunition and Explosives
- ATF 5400.7, Alcohol Tobacco and Firearms Explosives Laws and Regulations
- Applicable sections of DOT, 49 CFR 100 to 199.

4.0 RESPONSIBILITIES

4.1 PROJECT MANAGER

The Project Manager shall be responsible for ensuring the availability of the resources needed to implement this SOP, and shall also ensure that this SOP is incorporated in plans, procedures, and training for disposal of OE.

4.2 SENIOR OE SUPERVISOR

The Senior UXO Supervisor (SUXOS) will be responsible for assuring that adequate safety measures and housekeeping are taken during all phases of site operation, to include demolition activities, and shall visit site demolition locations routinely to ensure that demolition operations are carried out in a safe, clean, efficient, and economical manner.

4.3 DEMOLITION SUPERVISOR

Prior to initiation of demolition operations, the SUXOS shall designate an experienced and trained UXO Supervisor to act as the Demolition Supervisor (DS). The demolition activities shall then be conducted under the direct control of the DS, who will have the responsibility of supervising all demolition operations within the area. The DS shall be responsible for training all on-site OE personnel regarding the nature of the materials handled, the hazards involved and the precautions necessary. The DS will also ensure that the Daily Operational Log and Demolition Shot Records are properly filled and accurately depict the demolition events and demolition material consumption for each day's operations. The DS shall be present during all demolition operations or designate a competent, qualified person to be in charge during any absences.

4.4 SITE SAFETY OFFICER

The Site Safety Officer (SSO) for the site is responsible for ensuring that all demolition operations are being conducted in a safe and healthful manner, and is required to be present during all OE demolition operations. The only exception to this rule is when the project site has multiple sites conducting various types of OE investigation and remediation operations being conducted concurrently with periods where there may be continuous demolition operations throughout the day. In that event, a demolition team SSO will be designated. This individual will report to the SSO and assume the SSO's responsibilities at the demolition range. In this situation, the SSO will conduct periodic safety audits of the demolition team and assist the demolition team SSO in the performance of their duties. The SSO will report demolition safety issues directly to the OE Safety Manager (OESM).

4.5 QUALITY CONTROL SPECIALIST

The Quality Control Specialist (QCS) is responsible for ensuring the completeness of disposal operations and for weekly inspection of the Daily Operational Log and Demolition Shot Records. The QCS, assisted by demolition team personnel, will inspect each disposal site and the area encompassed by the "sand bag

throw" distance after each disposal shot to ensure there are no residual OE or components or recognizable OE scrap items. Any OE considered "unsafe to move" that is discovered during the QC check will be marked and disposed of by BIP that day. Extreme caution must be exercised when handling OE that has been exposed to the forces of detonation.

5.0 GENERAL OPERATIONAL AND SAFETY PROCEDURES

All personnel, including contractor and subcontractor personnel, involved in operations on OE-contaminated sites shall be familiar with the potential safety and health hazards associated with the conduct of demolition/disposal operations, and with the work practices and control techniques used to reduce or eliminate these hazards. During demolition operations, general safety provisions listed below shall be followed by all demolition personnel. Noncompliance with the general safety provisions listed may result in discipline, to include termination of employment:

- All safety regulations applicable to demolition activities shall be complied with.
- All requirements of OE SSHP shall be complied with.
- Demolition of any kind is prohibited without the express permission from the client.
- The use of sandbags or other engineering controls for mitigation of fragmentation and blast effects due to intentional detonation of munitions will be conducted in accordance with Appendix J of the OE RDD. The quantity of OE to be destroyed in a single shot will be limited to one item to reduce noise travel into residential areas.
- In the event of an electrical storm or heavy snow or dust storms, immediate action will be taken to cease all disposal site operations and evacuate the area.
- In the event of a fire or unplanned explosion, if possible, put out the fire. If unable to do so, notify the fire department and evacuate the area. If injuries are involved, remove victims from danger, administer first aid, and seek medical attention.
- The DS is responsible for reporting all injuries and accidents that occur during disposal operations to the SSO.
- Personnel on site will not tamper with any safety devices or protective equipment.
- Methods of demolition shall be conducted in accordance with this procedure and approved changes thereto.
- Adequate first aid equipment shall be provided at all times.
- All personnel engaged in the destruction of OE shall wear under and outer garments made of natural fiber, close-weave clothes, such as cotton. Synthetic material such as nylon is not authorized unless treated with anti-static material.
- Care will be taken to minimize exposure to the smallest number of personnel, for the shortest time, to the least amount of hazard, consistent with safe and efficient operations.

- Work locations will be maintained in a neat and orderly condition.
- All hand tools shall be maintained in a good state of repair.
- Each heavy equipment and/or vehicle operator will have in their possession a valid state driver's license.
- Equipment and other lifting devices designed and used for lifting will have the load rating and date of next inspection marked on them. The load rating will not be exceeded and the equipment will not be used without a current inspection date.
- Leather or leather-palmed gloves will be worn when handling wooden boxes, munitions, or OE.
- Lifting and carrying require care. Improper methods cause unnecessary strains. Observe the following preliminaries before attempting to lift or carry:
    - When lifting, keep your arms and back as straight as possible, bend your knees, and lift with your leg muscles; and
    - Be sure you have good footing and hold; lift with a smooth, even motion.
- Telephone and/or radio communication will be available and used during disposal operations.
- Motor vehicles and material handling equipment (MHE) used for transporting OEO or demolition materials must meet the following requirements:
    - Exhaust systems shall be kept in good mechanical repair at all times.
    - Lighting systems shall be an integral part of the vehicle.
    - One Class ABC-rated, portable fire extinguisher shall, if possible, be mounted on the vehicle outside of the cab, on the driver's side, and one Class ABC fire extinguisher shall be mounted inside the cab.
    - Wheels of carriers must be chocked and brakes set during loading and unloading.
    - No demolition material or OE shall be loaded into or unloaded from motor vehicles while their motors are running.
- Motor vehicles and handling equipment used to transport demolition material and OE shall be inspected prior to use to determine that:
    - Fire extinguishers are filled and in good working order.
    - Electrical wiring is in good condition and properly attached.
    - Fuel tank and piping are secure and not leaking.
    - Brakes, steering, and safety equipment are in good condition.
    - The exhaust system is not exposed to accumulations of grease, oil, gasoline, or other fuels, and has ample clearance from fuel lines and other combustible materials.

- Employees are required to wear leather or rubber gloves when handling demolition materials. The type of glove worn is dependent on the type of demolition material.

- An observer will be stationed at a location where there is a good view of the air and surface approaches to the disposal site before material is detonated. It shall be the responsibility of the observer to warn the DS to suspend firing if any aircraft, vehicles, or personnel are sighted approaching the disposal site.

- Two-way radios shall not be operated at the disposal site while the shot is primed or during the priming process. The charts shown in Tables I-1 and I-2 shall be used for determining the safe distances from transmitter antennas.

- Disposal operations will not be left unattended once explosives are on site and operations have begun.

- No disposal operations will be conducted if there is less than a 2,000-foot ceiling or if wind velocity exceeds 20 mph.

- Disposal shots must be fired during daylight hours (i.e., between 30 minutes after sunrise and 30 minutes before sunset).

- No more than two persons shall ride in a truck transporting demolition material or OE, and no passengers are authorized to ride in the trailer/bed.

- Vehicles shall not be refueled when carrying demolition material or OE, and must be 100 feet from magazines or trailers containing such items before refueling.

- All explosive vehicles will be cleaned of visible explosive and other contamination before releasing the vehicles for other tasks.

- Prior to conducting any other task, personnel shall clean their face and hands after handling demolition material or OE.

5.1 FIRE PREVENTION FOR DISPOSAL OPERATIONS

The following procedures will be adhered to on each disposal shot:

- For OE that cannot be moved, measures will be taken to carefully plan fire suppression accesses and procedures prior to detonating shots. All disposal and safety personnel will be fully briefed on fire suppression procedures.

- Immediately after the detonation, all safety personnel will report status of the disposal site.

- If fire or smoke in the vegetation surrounding the site is present, the demolition team will proceed immediately to the site with field fire suppression equipment and attempt to suppress any fires present.

- If a fire becomes uncontrollable, emergency notifications to local fire agencies will be made and all field workers will stand by to assist as necessary.

The fire prevention goals are to plan effectively for all potential fire suppression obstacles, ensure prevailing winds are not going to take potential smoke towards populated areas, ensure that adequate fire suppression equipment is on site, and keep vigilant communications with the local fire department during all disposal operations.

6.0 SPECIAL REQUIREMENTS FOR DEMOLITION ACTIVITIES

The following safety and operational requirements shall be followed during disposal site operations. Any deviations from this procedure shall be allowed only after receipt of written approval from the Earth Tech Project Manager and the client. Failure to adhere to the requirements and procedures listed in the paragraphs below could result in serious injury or death; therefore, complete compliance with these requirements will be strictly enforced.

6.1 GENERAL REQUIREMENTS

The general disposal operations requirements listed below shall be followed at all times:

- Material awaiting destruction shall be stored in the on-site storage magazine, until just before disposal is to take place.
- OE or bulk explosives to be destroyed by detonation should be detonated in a blast chamber or in a pit constructed as set forth in Section 4.11 of the OE RDD. The components should be placed on their sides or in a position to expose the largest area to the influence of the demolition material. The demolition material should be placed in direct contact with the item to be detonated and held in place by tape or earth packed over the demolition materials. The total quantity to be destroyed at one time shall be kept at a minimum.
- Detonations will be counted to ensure detonation. After each shot, a search shall be made of the surrounding area for OE. Items such as lumps of explosives or unfuzed ammunition may be picked up and prepared for the next shot.
- Prevailing weather condition information will be obtained from the U.S. Weather Service and the data logged in the Demolition Shot Log before each shot or round of shots.
- All shots shall be dual-primed.
- A minimum of 30 seconds will be maintained between each detonation.
- After each detonation and at the end of each day's operations, surface exposed scrap metal, casings, fragments, and related items shall be recovered from the disposal site and disposed of in accordance with OE scrap procedures, as well as all applicable environmental regulations. All collected scrap metal will be 100 percent inspected for absence of explosive materials by OE personnel and certified by the SUXOS.
- When operated in accordance with the conditions of this procedure, the disposal site should not present a noise problem to the surrounding community. However, if a noise complaint is received, the name, address, and telephone number of the complainant should be recorded and reported to the SUXOS who, in turn, shall report it to the Earth Tech Project Manager.

- Prior to and after each shot, the Demolition Shot Record is to be filled out by the DS with all applicable information.

6.2 ELECTRIC DETONATOR USE

The following requirements are necessary when using electric detonators and blasting circuits:

- Electric detonators and electric blasting circuits may be energized to dangerous levels from outside sources such as static electricity, induced electric currents, and radio communication equipment. Safety precautions will be taken to reduce the possibility of a premature detonation of the electric detonator and explosive charges of which they form a part. Radios will not be operated while the site is primed or during the priming process.

- The shunt shall not be removed from the leg wires of the detonator until the continuity check of the detonator.

- When uncoiling or straightening the detonator leg wires, keep the explosive end of the detonator pointing away from the body and away from other personnel. When straightening the leg wires, do not hold the detonator itself; rather, hold the detonator leg wires approximately 1 inch from the detonator body. Straighten the leg wires by hand; do not throw or wave the wires through the air to loosen them.

- Prior to use, the detonators shall be tested for continuity. To conduct the test, place the detonators in a pre-bored hole in the ground or place them in a sand bag, and walk facing away from the detonators and stretch the wires to their full length, or to 25 feet, whichever is less, being sure to not pull the detonators from the hole or sand bag. With the leg wires stretched to their full length, test the continuity of the detonators one at a time by un-shunting the leg wires and attaching them to the galvanometer and checking for continuity. After the test, re-shunt the wires by twisting the two ends together. Repeat this process for each detonator until all detonators have been tested. This process shall be accomplished at least 25 feet from any OE or demolition materials and out of the demolition range personnel and vehicle traffic flow pattern. In addition, all personnel on the demolition range shall be alerted prior to the test being conducted.

NOTE: When testing the detonator prior to connecting the detonator to the firing circuit, the leg wires of the detonator must be shunted by twisting the bare ends of the wires together immediately after testing. The wires shall remain short circuited until time to connect them to the firing line.

- At the power source end of the blasting circuit, the ends of the wires shall be shorted or twisted together (shunted) at all times, except when actually testing the circuit or firing the charge. The connection between the detonator and the circuit firing wires must not be made unless the power end of the firing wires are shorted and grounded or the firing panel is off and locked.

- The firing line will be checked using pre-arranged hand signals or through the use of two-way radios if the demolition pit is not visible from the firing point. If radios are used, communication shall be accomplished a minimum of 25 feet from the demolition pit and detonators. The firing line will be checked for electrical continuity in both the open and closed positions, and will be closed/shunted prior to connecting the detonator leg wires.

- OE to be detonated/vented shall be placed in the demolition pit or blast chamber and the demolition material placed/attached in such a manner as to ensure the total detonation/venting of the OE. Once the OE and demolition material are in place and the shot has been tamped, the detonators

will be connected to the demolition material. Prior to handling any detonators that are connected to the firing line, personnel shall ensure that they are grounded. The detonators will then be carried to the demolition pit with the end of the detonators pointed away from the individual. The detonators are then connected to the detonation cord, Non-El, etc., ensuring that the detonator is not covered with tamping material to allow for ease of recovery/investigation in the event of a misfire.

- Prior to making connections to the blasting machine, the entire firing circuit shall be tested with a galvanometer for electrical continuity and ohmic resistance to ensure the blasting machine has the capacity to initiate the shot.

- The individual assigned to make the connections at the blasting machine or panel will not complete the circuit at the blasting machine or panel and will not give the signal for detonation until satisfied that all personnel in the vicinity have been evacuated to a safe distance. When in use, the blasting machine or its actuating device shall be in the blaster's possession at all times. When using the panel, the switch must be locked in the open position until ready to fire, and the single key must be in the blaster's possession.

- Prior to initiating a demolition shot(s), a warning will be given, the type and duration of such will be determined by the prevailing conditions at the demolition range. At a minimum, this should be an audible signal using a siren, air horn or megaphone that is sounded for a duration of 1 minute, 5 minutes prior to the shot and again 1 minute prior to the shot.

6.3 DETONATING CORD USE

The following procedures are required when using detonating cord (det cord):

- Detonation cord should be cut using approved crimpers and only the amount required should be removed from inventory.

- When cutting the detonation cord, the task should be performed outside the magazine.

- For ease of inventory control, only remove the detonation cord in 1-foot increments.

- The detonation cord should not be placed in clothing pockets or around the neck, arm, or waist, and should be transported to the demolition location in either an approved "day box" or a cloth satchel, depending upon the magazine location and proximity to the demolition area.

- The detonation cord should be placed at least 25 feet away from detonators and demolition materials until ready for use. To ensure consistent safe handling, each classification of demolition material shall be separated by at least 25 feet until ready for use.

- When ready to "tie in" either the detonation cord to demolition materials, or the detonation cord to the detonator, the detonation cord will be connected to the demolition material and secured to the OE. The cord is then strung out of the hole and secured in place with soil, being sure to leave a 1-foot tail exposed outside the hole.

- Once the hole is filled, make a loop in the detonation cord that is large enough to accommodate the detonation cord detonator, place the detonator in the loop, and secure it with tape. The explosive end of the detonator will face down the detonation cord, toward the demolition material or parallel to the main line.

- In all cases, ensure there is sufficient detonation cord extending out of the hole to allow for ease of detonator attachment and detonator inspection/replacement should a misfire occur.

- If the detonation cord detonators are electric, they will be checked, tied in to the firing line, and shunted prior to being taped to the loop. If the detonation cord detonators are Non-El, the time/safety fuse will be prepared with the igniter in place prior to taping the detonators to the detonation cord loop. If the detonation cord detonators are non-electric, simply tape the detonators into the loop as described above.

- In the event that a time/safety fuse is used and an igniter is not available and a field expedient initiation system is used (i.e., matches), do not split the safety fuse until the detonator is taped into the detonation cord loop.

6.4 TIME/SAFETY FUSE USE

The following procedures are required when using a time/safety fuse:

- Prior to each daily use, the burn rate for the time/safety fuse must be tested to ensure the accurate determination of the length of time/safety fuse needed to achieve the minimum burn time of 5 minutes needed to conduct demolition operations.

- To ensure both ends of the time/safety fuse are moisture-free, use approved crimpers to cut 6 inches off the end of the time/safety fuse roll, and place the 6-inch piece in the time/safety fuse container.

- Take the 6-foot section out of the magazine and attach a fuse igniter.

- In a safe location, removed from demolition materials and OE, ignite the time/safety fuse, measure the burn time from the point of initiation to the "spit" at the end, and record the burn time in the DS's Log.

- To measure the burn time, use a watch with a second hand or chronograph.

- To calculate the burn rate in seconds per foot, divide the total burn time (in seconds) by the length (in feet) of the test fuse.

- Whenever using time/safety fuse for demolition operations, the minimum amount of fuse to be used for each shot will be the amount needed to permit a minimum burn time of 5 minutes.

6.5 PERFORATOR USE

The following procedures are required when using perforators:

- Only remove from inventory the number of perforators required to perform the task.

- Transport perforators in an approved "day box," cloth satchel, or plastic container, depending upon magazine location and proximity to the demolition operations.

- Keep perforators stored at the demolition site at least 25 feet away from detonators and demolition materials until ready for use.

- When ready to use, place the detonation cord through the slot on the perforator and knot the detonation cord, ensuring the cord fits securely and has good continuity with the perforator.
- Once the detonation cord is secure, place the perforator in the desired location and secure it in place.
- Proceed from this point as described in Section 6.3.

6.6 USE OF TWO-COMPONENT EXPLOSIVES

The following procedures are required when using two-component explosives as demolition material:

- Only remove from inventory the amount of two-component required to perform the task.
- When transporting the solid and liquid, they need only be placed apart in the bed of a truck.
- Do not mix the solid and liquid components until certain that it will be used, since the resulting mixture is classified as a Class 1.1 explosive by Department of Transportation.
- When mixing the solid and liquids components, follow the manufacturer's instructions, while being sure to wear rubber gloves and goggles. Mix components in an area away from other demolition materials, the OE, and if possible, sheltered from the wind.
- Once the components have been mixed, it is essential that the lid to the solid bottle is put on securely as soon as possible after mixing to prevent evaporation of the liquid.
- Attach the detonation cord as recommended by the manufacturer, place the assembled unit in the desired location in the hole, and secure the unit.
- Proceed from this point as described in Section 6.3.

7.0 METEOROLOGICAL CONDITIONS

In order to control the effects of demolition operations and to ensure the safety of site personnel, the following meteorological limitations and requirements shall apply to demolition operations:

- Demolition operations will not be conducted during electrical storms or thunderstorms.
- No demolition operations shall be conducted if the surface wind speed is greater than 10 miles per hour.
- Demolition operations will not be conducted during periods of visibility of less than 1 mile caused by, but not limited to, dense fog, blowing snow, rain, sand, or dust storms.
- Demolition shall not be carried out on extremely cloudy days, which are defined as overcast (more than 80 percent cloud cover) with a ceiling of less than 2,000 feet.
- Demolition operations will not be conducted during any atmospheric inversion condition (low or high altitude).

- Demolition operations will not be conducted during periods of local air quality advisories.

- Demolition operations will not be initiated until 30 minutes after sunrise, and will be secured at least 30 minutes prior to sunset.

8.0 PRE-DEMOLITION/DISPOSAL PROCEDURES

8.1 PRE-DEMO/DISPOSAL OPERATIONAL BRIEFING

The DS will brief all personnel involved demolition operations in the following areas:

- Type of OE being destroyed
- Type, placement, and quantity of demolition material being used
- Use of sandbags for mitigation of fragmentation and blast effects
- Method of initiation (electric, non-electric or Non-EI)
- Means of transporting and packaging OE
- Route to the disposal site
- Equipment being used (e.g., galvanometer, blasting machine, firing wire)
- Misfire procedures
- Fire prevention procedures
- Post shot clean up of site.

8.2 PRE-DEMO/DISPOSAL SAFETY BRIEFING

The SSO will conduct a safety briefing for all personnel involved in operations in the following areas:

- Care and handling of explosive materials

- Personal hygiene

- Two man rule

- Potential trip/fall hazards

- Location of emergency shelter (if available)

- Parking area for vehicles (vehicles must be positioned for immediate departure, with the keys in the ignition)

- Location of emergency vehicle (keep engine running)

- Wind direction (to assess potential toxic fumes)

- Location of first aid kit and fire extinguishers

- Route to nearest hospital or emergency aid station

- Type of communications in event of an emergency.

8.3 TASK ASSIGNMENTS

Individuals with assigned tasks will report the completion of the task to the DS. The types of tasks that may be required are:

- Contact local police, fire personnel, and FAA as required.
- Contact hospital/emergency response personnel if applicable.
- Secure all access roads to the disposal site.
- Visually check PWD for any unauthorized personnel.
- Check firing wire for continuity and shunt.
- Prepare designated disposal sites as required.
- Check continuity of detonators.
- Check time/safety fuse and its burn rate.
- Designate a technician to maintain custody of blasting machine, fuse igniters, or Non-EI initiator.
- Secure detonators in a safe location.
- Place OE in pit and place charge in desired location.

8.4 PREPARING EXPLOSIVE CHARGE FOR INITIATION

To prepare the explosive charge for initiation, the procedures listed below will be followed:

- Ensure firing wire is shunted.
- Connect detonator to the firing wire.
- Isolate or insulate all connections.
- Place demolition charge on OE.
- Prime the demolition charge.
- Depart to firing point (if using non-electric firing system, obtain head count, pull igniters, and depart to designated safe area).
- Ensure all personnel are withdrawn to a safe distance (safe distance may vary depending on mitigation measures used). .
- Give 1-minute warning signal, using a bullhorn or siren, 5 minutes prior to detonation, and again at 1 minute prior to detonation.
- Yell **"fire in the hole"** three times (or an equivalent warning) and take cover.
- If using electric firing system, connect firing wires to blasting machine, and initiate charge.
- Remove firing wires from blasting machine and shunt.
- Remain in designated safe area until DS announces "**All Clear**." This will occur after a post-shot waiting period of 5-minutes and the DS has inspected the site(s).

9.0 POST DEMOLITION/DISPOSAL PROCEDURES

Do not approach a smoking hole or allow personnel out of the designated safe area until cleared to do so, and follow the below listed procedures:

- After the **"All Clear"** signal, check site for low orders, kick outs, and fires.
- Inspect inside of the Blast Chamber for low orders, as necessary, and remove all debris.
- Inspect site and dispose of any residual OE or recognizable OE scrap.
- Backfill hole as necessary.
- Police up all equipment.
- Notify police, fire, etc., that the operation is complete.

10.0 MISFIRE PROCEDURES

A thorough check of all equipment, firing wire, and detonators will prevent most misfires. However, if a misfire does occur, the procedures outlined below shall be followed.

10.1 ELECTRIC MISFIRES

To prevent electric misfires, one technician will be responsible for all electrical wiring in the circuit. If a misfire does occur, it must be cleared with extreme caution, and the responsible technician will investigate and correct the situation using the steps outlined below:

- Check firing line connections to the blasting machine and make a second attempt to initiate charge.
- If unsuccessful, disconnect and connect to another blasting machine (if available) and attempt to initiate charge.
- If unsuccessful, commence a 30-minute wait period.
- After the maximum delay predicted for any part of the shot has passed, the designated technician will proceed to the site to inspect the firing system, and a safety observer must watch from a protected area.
- Disconnect and shunt the detonator wires, connect a new detonator to the firing circuit, and prime the charge without disturbing the original detonator (replacement detonator must have been checked for continuity as outlined in Section 6.2, after disconnecting the defective detonator).
- Follow normal procedures for effecting initiation of the charge.

10.2 NON-ELECTRIC MISFIRES

Working on a non-electric misfire is the most hazardous of all operations. Investigation and corrective action should be undertaken by the technician that placed the charge using the following procedure:

- If a charge fails to detonate at the determined time, initiate a 60-minute wait period plus the time of the safety fuse (i.e., 5-minute safety fuse plus 60 minutes, for a total of 65-minute wait period).

- After the wait period has expired, a designated technician will proceed to the site to inspect the firing system. A safety observer must watch from a protected area.
- Prime the shot with a new non electric firing system and install a new fuse igniter.
- Follow normal procedures for initiation of the charge.

10.3 NON-EL MISFIRE

The use of a shock tube for blast initiation can present misfires which require the following actions:

- If charge fails to detonate, it could be the result of the shock tube not firing. Visually inspect the shock tube, if it is not discolored (i.e., slightly black), it has not fired.
- If it has not fired, cut a 1-foot piece off the end of the tube, re-insert the tube into the firing device, and attempt to fire again.
- If the device still does not fire, wait 30 minutes and proceed to the site to replace the shock tube with a new tube.
- If the tube is slightly black, then a "Black Tube" misfire has occurred, and the shock tube will have to be replaced. When replacing the shock tube, be sure to remove the tube with the detonator in place. Without removing the detonator from the end of the tube, place the defective tube on the shot for disposal.

10.4 DETONATING CORD MISFIRE

The detonation cord will be used to tie in multiple demolition shots and to ensure that electric detonators are not buried. Since detonation cord initiation will be either electrical or non-electrical, the procedures presented in Sections 10.1, 10.2, or 10.3, as appropriate to the type of detonator used, will be used to clear a detonation cord misfire. In addition, the following will be conducted:

- If there is no problem with the initiating system, wait the prescribed amount of time and inspect the initiator to the cord connection to ensure it is properly connected. If it was a bad connection simply attach a new initiator and follow the appropriate procedures in Section 6.0.
- If the initiator detonated and the cord did not, inspect the cord to ensure it is the detonation cord and not the time fuse. Also, check to ensure there is PETN in the cord at the connection to the initiator.
- At this point, it may be necessary to uncover the detonation cord and replace it. If this is required, it must be accomplished carefully to ensure that the demolition charge and the OE item(s) are not disturbed.

10.5 PERFORATOR MISFIRE

The use of perforators is both cost-effective and considerably safer than the use of C-4 and many other demolition materials. However, if the perforator is not initiated properly, it could malfunction. Since the perforator is covered with tamping material, the detonation cord is used as the initiator. Therefore, in the

event of a misfire, the procedures presented in Section 10.4 will be followed, along with the items presented below.

- If everything went but the perforator, one of four things has occurred:
  - The detonation cord grain size was insufficient to initiate the perforator
  - The detonation cord was dislodged from the perforator when placing tamping materials
  - The perforator was defective
  - The perforator was moved during the placement of tamping materials.

- Check to ensure the grain size of the detonation cord is sufficient, with 80 grain size or greater being the recommended size.

- If the detonation cord connection to the perforator was the problem, ensure that the next connection is secure (use duct tape if necessary).

- If it is evident that the perforator was moved, then ensure it is properly secured for the next shot.

- If cord size and connection are sufficient, replace the perforator, leaving the defective one on the shot

11.0 RECORD KEEPING REQUIREMENT

To document the demolition operations procedures and the completeness of the demolition of OE, the following record keeping requirements shall be met:

- Earth Tech will obtain and maintain all required permits.

- The DS will ensure the accurate completion of the logs, and the SUXOS will monitor the entries in the log for completeness, accuracy, and compliance with meteorological conditions.

- The DS shall enter the appropriate data on the Demolition Shot Record to reflect the OE destroyed.

- The quantities of OE recovered must also be the quantities of OE destroyed or disposed of as scrap.

- Earth Tech will retain a permanent file of all Demolition Records, including permits, training records, inspector reports, waste manifests if applicable, and operating logs.

- Copies of ATF License and any state or local permits must be on hand.

12.0 SAFETY AND PPE REQUIREMENTS

The following safety measures and personal protective equipment (PPE) shall be used in preventing or reducing exposure to the hazards associated with OE demolition/disposal operations. These requirements will be implemented unless superseded by site-specific requirements stated in the SSHP.

- Steel-toed safety boots will not be worn by personnel conducting demolition/disposal operations, unless a toe crush hazard exists, in which case personnel will wear boots with plastic or fiber toed safety toes;

- Unless a serious head, eye, or face hazard exists, OE personnel will not be required to wear hard hats, safety glasses, or face shields when conducting operations involving the handling of demolition explosives or OE; and

- In the event that a serious head, eye, or face hazard does exist, OE personnel will wear the required PPE, but positive means shall be required to secure the PPE and prevent it from falling and causing an accidental detonation.

13.0 AUDIT CRITERIA

The following items related to demolition/disposal operations on an OE contaminated site will be audited to ensure compliance with these SOPs:

- The Demolition Shot Record
- The Site Daily Operational and Safety Logs
- The OE Operations Daily/Weekly Report
- The Safety Training Attendance Forms, for the initial site hazard training
- The Safety Training Attendance Forms, for the Daily Tailgate Safety Briefings
- The Daily Safety Inspection and Audit Log.

TABLE I-1.
MINIMUM SAFE DISTANCE FROM TRANSMITTER ANTENNAS

Average or Peak Transmitter Power in Watts	Minimum Distance to Transmitter in Meters / Feet
0 - 5	7.5 / 25
6 - 30	30 / 98.4
31 - 50	50 / 164.1
51 - 100	110 / 360
101 - 250	160 / 525
251 - 500	230 / 755
501 - 1,000	305 / 1,000
1,001 - 3,000	480 / 1,575
3,001 - 5,000	610 / 2,001
5,001 - 20,000	915 / 3,002
20,001 - 50,000	1,530 / 5,020
50,001 - 100,000	3,050 / 10,007
100,001 - 400,000	6,100 / 20,014
400,001 - 1,600,000	12,200 / 40,028
1,600,001 - 6,400,000	24,400 / 80,056

Note: When the transmission is a pulsed or pulsed continuous wave type and its pulse width is less than 10 microseconds, the power column indicates average power. For all other transmissions, including those with pulse widths greater than 10 microseconds, the power column indicates peak power.

TABLE I-2.
MINIMUM SAFE SEPARATION FORMULAS

Unknown (Worst Case)	Without Metal Pack		With Metal Pack	
	Frequency	Formula	Frequency	Formula
Use Table 120D-1-1	≤2.3 KHz	$D = 0.093 \times (PG)^{0.5}$	≤73 KHz	$D = 0.093 \times (PG)^{0.5}$
	2.3 KHz - 0.45 MHZ	$D = 39.7 \times F \times (PG)^{0.5}$	73 KHz - 0.45 MHZ	$D = 126 \times F \times (PG)^{0.5}$
	0.45 MHZ - 400 MHZ	$D = 18 \times (PG)^{0.5}$	0.45 MHZ - 400 MHZ	$D = 0.6 \times (PG)^{0.5}$
	400 MHZ - 75 GHz	$D = (7137 / F) \times (PG)^{0.5}$	400 MHZ - 2.4 GHz	$D = (226 / F) \times (PG)^{0.5}$
	>75 GHz	$D = 0.093 \times (PG)^{0.5}$	>2.4 GHz	$D = 0.093 \times (PG)^{0.5}$

Where :

D = Safe distance to the transmitter in feet (multiply feet by 0.305 to obtain meters)

P = Output power of the transmitter in watts

G = Numerical gain of transmitter antenna

F = Frequency in MHZ (divide KHz by 1,000 to obtain MHZ, and multiply GHz by 1,000 to obtain MHZ)

To properly use this table, the following assumptions are made:

- The no-fire current of the EED is 10 mA.
- At least 10 dB below the no-fire current in EED is considered to be safe.
- The metal pack provides at least 30 dB of shielding.
- Non-metal packs provide no shielding.
- A 1 volt/meter field intensity is considered to be safe.
- At no time should personnel or munitions be exposed to more than 200 volts/meter.

APPENDIX J

BLOW-IN-PLACE ENGINEERING CONTROLS

US Army Corps
of Engineers
Engineering and Support
Center, Huntsville

Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions

HNC-ED-CS-S-98-7
AUGUST 1998

DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD
2461 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22331-0600

DDESB-KO

23 February 1999

MEMORANDUM FOR DIRECTOR US ARMY TECHNICAL CENTER FOR EXPLOSIVES SAFETY (ATTENTION: SIOAC-ES)

SUBJECT: Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonations of Munitions, Report HNC-ED-CS-S-98-7 (August 1998)

References: (a) SIOAC-ESL memorandum, dated 30 Nov 98, same subject

(b) Joseph M. Serena and Michelle Crull, "Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonations of Munitions, Report HNC-ED-CS-S-98-7," (August 1998)

The subject site plan forwarded by reference (a) has been reviewed with respect to explosives safety criteria. The site plan addresses the use of sandbags, IAW reference (b) to mitigate hazards and protect personnel from intentional detonations of munitions up to the 155-mm M107. Based on the information furnished, the proposed use of sandbags for intentional detonations at ordnance and explosives (OE) sites, IAW reference (b) is approved.

A copy of this site plan package and this letter of approval must be available at OE sites where intentional detonations are conducted that use procedures of this siting package.

Point of contact is Dr. Chester E. Canada, DDESB-KT2 (PH: commercial: 703-325-1369, FAX: 703-325-6227, E-MAIL: canadce@hqda.army.mil).

DANIEL T. TOMPKINS
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Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions

Prepared by
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August 1998

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EXECUTIVE SUMMARY

The U.S. Army Engineering and Support Center, Huntsville (USAESCH) is currently engaged in projects which require the disposal of uncovered/discarded ordnance and explosives (OE) on public and private lands. The uncovered OE item is often detonated in place if it is too dangerous to move. In some cases, covering and tamping with loose earth is used to contain the blast and fragments. Another method to mitigate the fragmentation and blast effects is to cover the item with sandbags. However, traditionally there has been no method to determine the optimum configuration or the required thickness of such a sandbag enclosure.

The Structural Branch, USAESCH, sponsored a test program in 1997 to evaluate the use of sandbag enclosures for fragment and blast mitigation, for intentional detonations at Ordnance and Explosives (OE) sites. Southwest Research Institute (SwRI), under contract to USAESCH, performed a two phase test program of sandbag enclosures. In phase one, the preliminary explosive test phase, four tests on a 155-mm projectile were performed to refine and optimize the test procedure. This test procedure was used in phase two, the comprehensive explosive test phase. In phase two, a total of fourteen tests with five different munitions were performed to determine the thickness of sandbags required to capture all primary fragments. Measurements were made of the overpressures at various places, sandbag throw distances, depth of fragment penetration, and noise levels. High-speed film cameras, video recorders and digital cameras were used to visually record the events.

Required Wall and Roof Thicknesses for Sandbag Enclosures, with Expected Sandbag Throw Distances and Pressures, for Five Tested Munitions

Munition	Charge Weight, Comp B, lb	Required Wall and Roof Sandbag Thickness, in	Expected Maximum Sandbag Throw Distance, ft	Expected Peak Pressure @ 40 feet, psi	Expected Peak Pressure @ 80 feet, psi	Expected Sound Level @ 100 feet, dB
155-mm M107	15.4	36	220	0.18	0.09	115
4.2-in M329A2	8.17 (TNT)	24	125	0.16	0.06	116
105-mm M1	5.08	24	135	0.18	0.08	120
81-mm M374A2	2.1	20	125	0.14	0.05	119
60-mm M49A3	0.43	12	25	0.08	0.03	118

The results of these tests have been used to develop guidelines for the use of sandbag enclosures. The guidelines include required sandbag thicknesses, configuration and construction of the sandbag enclosures, and withdrawal distances based on the greater of sandbag throw distances or 200 ft. This document provides a summary of the test results and these guidelines.

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1.0 Introduction

The U.S. Army Engineering and Support Center, Huntsville (USAESCH) is currently engaged in projects which require the disposal of uncovered/discarded ordnance and explosives (OE) on public and private lands. The uncovered OE item is often detonated in place if it is too dangerous to move. In some cases, covering and tamping with loose earth is used to contain the blast and fragments. Another method to mitigate the fragmentation and blast effects is to cover the item with sandbags. However, traditionally there has been no method to determine the optimum configuration or the required thickness of such a sandbag enclosure.

The Structural Branch, USAESCH, sponsored a test program in 1997 to evaluate the use of sandbag enclosures for fragment and blast mitigation, for intentional detonations at Ordnance and Explosives (OE) sites. Southwest Research Institute (SwRI), under contract to USAESCH, performed a two phase test program of sandbag enclosures. In phase one, the preliminary explosive test phase, four tests on a 155-mm projectile were performed to refine and optimize the test procedure. This test procedure was used in phase two, the comprehensive explosive test phase. In phase two, a total of fourteen tests with five different munitions were performed to determine the thickness of sandbags required to capture all primary fragments. Measurements were made of the overpressures at various places, sandbag throw distances, depth of fragment penetration, and noise levels. High-speed film cameras, video recorders and digital cameras were used to visually record the events.

The results of these tests have been used to develop guidelines for the use of sandbag enclosures. The guidelines include required sandbag thicknesses, configuration and construction of the sandbag enclosures, and withdrawal distances based on the greater of sandbag throw distances or 200 ft. This document provides a summary of the test results and these guidelines.

2.0 Test Program

2.1 Fragmentation Characteristics of Munitions

Prior to beginning this test program the fragmentation characteristics of a variety of munitions frequently encountered during OE site operations were determined. The fragmentation characteristics were calculated in accordance with procedures outlined in TM5-1300, "Structures to Resist the Effects of Accidental Explosions" [1] and detailed in CEHNC-ED-CS-S-98-1, "Methods for Predicting Primary Fragmentation Characteristics of Cased Explosives" [2]. The fragmentation characteristics were used to predict preliminary thicknesses of sand required to prevent perforation for the five munitions tested.

Optimally, the fragments from the munition will strike the sandbags before the blast wave so that the fragments are penetrating undisturbed sand. To ensure that this will

occur it is necessary to reduce the coupling between the explosive charge and the surrounding soil. This coupling is dependent on the separation distance between the charge and the soil. Full coupling implies that the maximum amount of energy, or velocity, is transferred from the explosive into the soil immediately adjacent to the charge. If an explosive charge is placed in a cavity, so that an air gap exists between the charge and the walls of the cavity, coupling between the explosive and soil is reduced. Therefore, a standoff of some distance is required to reduce the coupling effect. Calculations to determine the velocity of sand particles from a buried explosion were performed. The velocity of the sand particles was compared to the velocity of the design fragment through sand. These calculations suggest that at a distance between 6 and 12 inches from the explosion, the fragment velocity exceeds the particle velocity. Therefore, the initial standoff distances for the tests were 6 and 12 inches.

2.2 Preliminary Explosive Test Phase

In the preliminary explosive tests, four tests of statically detonated 155-mm M107 projectiles were performed. These tests provided the data needed to specify the amount and configuration of sandbags that are required to safely detonate a 155-mm projectile in place, verified that the general test procedure was satisfactory, and defined the instrumentation and data acquisition systems for the subsequent comprehensive explosive tests. Figure 1 shows the site layout for the tests of sandbag enclosures. Although, munitions are rarely oriented vertically for demolition in place, the vertical orientation provided the opportunity to evaluate a greater number of combinations of wall thicknesses and standoff distances. Figures 2 and 3 show the sandbag enclosure configurations for vertical and horizontal weapon tests.

The test matrix for the preliminary explosive tests is shown in Table 1. Two tests were run with the 155-mm in the vertical orientation and two in the horizontal orientation. Each test allowed five standoff distances and five sandbag thicknesses to be evaluated.

The sandbags were made of woven polypropylene, as is commonly used by explosives and ordnance disposal (EOD) personnel, and the volume/weight of the sandbags was either 0.5 ft^3/50 lbs for the large bags or 0.25 ft^3/25 lbs for the small bags. The small bags were used for test two. No additional information was provided by using the small bags so these were not used for any other tests. The bags were filled with a "washed river" sand that was judged to be "typical" by a local soil consultant (Fugro-McClelland Southwest, Inc.).

To determine the sandbag throw distribution some of the sandbags in the first two tests were filled with sand colored with dye. The dye did not improve the quality of the test results. Spray paint was used in the subsequent tests to mark each bag with its original position in the sandbag enclosure. A different color was used to indicate the wall or the roof and numbers were used to indicate the layer in which the sandbag was located.

Detailed descriptions of all tests and results are provided in "Evaluation of Sandbags for Fragment and Blast Mitigation" by Southwest Research Institute [3].

Table 1 – Test Matrix for Preliminary Explosive Tests

Test No.	Orientation	Standoff, in.					Wall Thickness, in. (Bag Size)				Wall Height in. (Bag Size)	
		S_1	S_2	S_3	S_4	S_R	T_1	T_2	T_3	T_4	H_1	H_2
155-1	Vertical	12	6	6	12	6	32	32.5	45	43	32	20
155-2	Vertical	6	6	6	6	6	18(s)	54	18(s)	53(s)	32	22
155-3	Horizontal	6	6	6	6	6	30	48	24	24	12	30
155-4	Horizontal	6	6	6	6	6	35	36	34	36	12	36

Note: All walls were constructed with large bags, except for those designated with an "s" for small bags.

2.2.1 Preliminary Explosive Test Results

For tests 1 and 2, the 155-mm M107 projectile was detonated using a donor charge of 200 g of C-4 placed in the fuze well and initiated with an Exploding Bridge Wire. For tests 3 and 4, the 155-mm M107 projectile was detonated using a well perforator shaped charge. This approach is typically used for on-site detonations. Time of arrival (TOA) pins were used for all tests to determine if a high order detonation was achieved.

All detonations were high order and results were obtained. The make screens and their frames and the assorted witness screens were scattered across the site. Where possible, each screen was identified and photographed and the number of fragment holes or the condition of the screen was recorded. The results of the first three tests suggested that a wall and roof thickness of 36 inches should be sufficient to contain all of the fragments and to reduce the overpressure levels. The dimensions of test 4 confirmed this configuration.

From the limited data collected on standoff distance, it appears that for standoffs of 6 and 12 inches there is no difference in the thickness of sandbags required to stop fragments. Test 2 showed that the size of the sandbag did not affect the fragment penetration. Test 3 showed that the horizontal orientation of the munition did not greatly effect the fragment penetration. Tests 3 and 4 showed that the base plate of the munition broke up and was stopped by 24 inches or less of sandbags.

The data collected showed that approximately 20 inches of sandbags will completely contain the fragments from the 155-mm M107 projectile. The only indications of fragments exiting the sandbag enclosure came from the two identical 18 inch walls of test 2 (external witness screens on sides 1 and 3 both registered fragment impacts). Internal witness screens at depths of 20 inches to 24 inches for all 4 tests did not indicate any fragment impacts. In tests 2 through 4, the roof witness screens also showed no penetrations for 20 to 36 inches of roof depth. The CONWEP software [4]

predicts that 24 inches of sand will stop the design fragment from the 155-mm M107 projectile.

Sandbag throw distances were recorded in 10 foot increments from ground zero to the furthest sandbags. The maximum sandbag throw distances were 150 feet, 191 feet, 157 feet, and 150 feet for tests 1 through 4, respectively. All of the furthest thrown sandbags came from the roof. In most cases, the roof sandbags were found relatively intact while the wall sandbags were often disintegrated. The bulk of the sandbags fell within 100 feet with only a few beyond this distance. An examination of the sandbag throw distances show that the standoff, the size of the bag, and the weapon orientation did not affect the throw distance to any significant degree.

Blast overpressures were recorded for all 4 tests (see Table 2). As shown, the sandbag enclosures greatly reduced the magnitude of the pressure. In test 3, a digital sound meter was placed 100 feet from ground zero and the maximum sound level recorded was 114.7 decibels.

Table 2 – Blast Overpressures from Preliminary Explosive Tests

Test No.	Side 1				Side 4			
	P1 @ 40', psi	P2 @ 40', psi	P3 @ 80', psi	P4 @ 80', psi	P5 @ 40', psi	P6 @ 40', psi	P7 @ 80', psi	P8 @ 80', psi
155-1	0.67	0.71	ND	ND	0.37	0.38	ND	ND
155-2	1.31	1.18	ND	ND	0.74	0.97	ND	ND
155-3	0.16	0.16	0.07	0.06	0.16	0.18	0.09	ND
155-4	0.04	0.04	0.03	0.03	0.07	0.08	ND	0.05

ND = no data

2.3 Comprehensive Explosive Tests

An additional fourteen tests were performed: one more using 155-mm M107 projectiles, four using 105-mm M1 projectiles, three using 4.2-in M329A2 projectiles, four using 81-mm M374A2 mortars, and two using 60-mm M49A3 mortars. The test matrix for the comprehensive explosive tests is shown in Table 3. For all tests performed with the munition in the vertical orientation, detonation was achieved using a donor charge of 100 grams (50 grams for test 60-1) of C-4 in the fuze well. For all tests performed with the munition in the horizontal orientation, detonation was achieved using a well perforator. TOA pins were used for all tests to check if a high order detonation was achieved.

For each of the comprehensive explosive tests, woven polypropylene 0.5 ft^3 sandbags were filled with 50 lbs of washed river sand. The sandbags were painted and numbered as described in Section 2.2 to indicate their original position in the sandbag enclosure. Moisture content was not controlled nor monitored during the test program.

Pressure gages, a sound meter, high speed cameras, digital cameras and video cameras were used for data acquisition during each test. Internal and external witness screens were used to determine how deeply the fragments moved into the sandbag mass and whether any fragments exited the sandbag enclosure.

Table 3 – Test Matrix for Comprehensive Explosive Tests

Test No.	Orientation	Standoff, in.					Wall Thickness, in.				Wall Height, in.	
		S_1	S_2	S_3	S_4	S_R	T_1	T_2	T_3	T_4	H_1	H_2
155-5	Horizontal	7	7	5	6	7	36	36	36	36	13	36
4.2-1	Vertical	5.5	5.5	5.5	5.5	6	20	24	31	36	19	24
4.2-2	Horizontal	6.5	6.5	6	6	7	24	25	24	24	11	24
4.2-3	Horizontal	6	5	5	6	7	24	25	25	24	11	24
105-1	Vertical	5.5	5.5	5.5	5.5	6	20	26	31	35	25	24
105-2	Vertical	0	0	4	6	6	29	25	19	25	26	23
105-3	Horizontal	7	5	5	5	9	24	24	24	24	13	24
105-4	Horizontal	6.5	6	5	6	7	25	25	24	24	11	23
81-1	Vertical	5	5	6	6	6	12	19	23	30	15	18
81-2	Horizontal	7	6	5.5	7	6	18	24	18	24	9	18
81-3	Horizontal	7	6	5	6	7	18	19	18	19	10	18
81-4	Horizontal	6	5.5	5.5	5.5	8	19	20	19	20	11	18
60-1	Vertical	6	6	6	6	6	13	19	23	30	11	12
60-2	Horizontal	6.5	3	5.5	3	6	12	12	12	12	8	13

All detonations were high order and results were obtained. The assorted witness screens were scattered across the site. Where possible, each screen was identified and photographed and the number of fragment holes or the condition of the screen was recorded. Sandbag throw distances were recorded in 10 foot increments from ground zero to the furthest sandbags. Blast overpressures were recorded for all tests at 40 feet and 80 feet from ground zero. A digital sound meter was placed 100 feet from ground zero. A summary of the results is shown in Table 4.

The final test for each munition was a confirmation test. These included tests 155-5, 4.2-3, 105-4, 81-3 and 60-2. The purpose of the confirmation tests was to model as closely as possible the actual use of sandbags in field conditions. In each test the internal witness screens were omitted. Sandbags were staggered both horizontally and vertically. External witness screens were placed over the roof and the two sides facing away from the pressure gages. After each test, the external witness screens were recovered and inspected for fragment penetrations. No such penetrations were identified. Therefore, the sandbag thicknesses defined in Table 4 are those used in the confirmation tests. For two munitions, the penetration data from internal witness panels suggests that somewhat smaller sandbag thicknesses may be sufficient to capture all fragments. As stated above for the 155-mm M107, internal witness screens show no fragment penetrations for sandbag thicknesses of about 24 inches or more. For the

4.2-inch M329A2 mortar, the internal witness screens show no fragment penetrations deeper than about 18 inches. However, the thicknesses of 36 inches for the 155-mm M107 and 24 inches for the 4.2-inch M329A2 are retained for use in the field, since sandbag throw distances are based on these thicknesses. While possibly thicker than necessary from capturing fragments, the increased total mass of the sandbags results in reduced sandbag throw distances.

Detailed descriptions of all tests and results are provided in "Evaluation of Sandbags for Fragment and Blast Mitigation" by Southwest Research Institute [3].

3.0 Guidelines for Use of Sandbags

3.1 Enclosure Geometry

Table 5 summarizes the results of the tests. This table specifies the minimum thickness of sandbag walls and roof that is needed to completely contain the fragments for the five munitions that were tested in this project. It also gives the expected maximum sandbag throw distances, the peak pressures at 40 feet and 80 feet, and the sound level at 100 feet, for the five munitions. For safety and conservatism, the expected sandbag throw distances are approximately 10% larger than the largest distances actually measured in the tests. Thus, the expected sandbag throw distances given in Table 5 are conservative in two ways: first, the largest measured sandbag throw distance from all tests of a particular round is used and second, this value is increased by 10%. Due to the already low values of peak pressures, a similar increase in the expected peak pressures was not deemed necessary or justified.

Table 4 – Summary of Results from Comprehensive Explosive Tests

Munition	Sandbag Thickness (in) to Defeat Fragments	Max. Sandbag Throw Distance (ft)		Max Peak Overpressure (psi) @ 40 ft		Max Peak Overpressure (psi) @ 80 ft		Max Noise Level (dB) at 100 ft
		Side of Round	Nose/Tail of Round	Side of Round	Nose of Round	Side of Round	Nose of Round	
155-mm M107	36	200	130	0.06	0.12	0.04	0.05	114.7
4.2-in M329A2	24	110	70	0.12	0.14	0.04	0.06	115.8
105-mm M1	24	120	50	0.17	0.18	0.07	0.08	119.3
81-mm M374A1	20	110	30	0.14	0.08	0.05	0.03	118.3
60-mm M49A3	12	20	20	0.06	0.08	0.02	0.03	117.3

Obviously, the five munition types do not cover all of the munitions that may be encountered. To determine the minimum wall and roof thickness for a particular shell other than those found in Table 5, the approach is as follows:

(1) Determine the initial fragment velocity (V_F) in ft/s, the maximum fragment weight (W_F) in pounds, and the kinetic energy ($W_F V_F^2/2$) in lb-ft^2/s^2 for the particular munition.

(2) Identify the munition with the next largest kinetic energy, from Table 6.

(3) Use the sandbag wall and roof thickness from Table 5 for the munition with the next largest kinetic energy shown in Table 6.

Table 6 provides the maximum fragment weight, the initial fragment velocity, and the resulting kinetic energy for the 5 munition types. The maximum fragment weight and the initial fragment velocity values were determined with the Mott and Gurney equations, as presented in TM 5-1300 [1] and detailed in HNC-ED-CS-S-98-1 [2].

Table 5 - Required Wall and Roof Thicknesses for Sandbag Enclosures, with Expected Sandbag Throw Distances and Pressures, for Five Tested Munitions

Munition	Charge Weight, Comp B, lb	Required Wall and Roof Sandbag Thickness, in	Expected Maximum Sandbag Throw Distance, ft	Expected Peak Pressure @ 40 feet, psi	Expected Peak Pressure @ 80 feet, psi	Expected Sound Level @ 100 feet, dB
155-mm M107	15.4	36	220	0.18	0.09	115
4.2-in M329A2	8.17 (TNT)	24	125	0.16	0.06	116
105-mm M1	5.08	24	135	0.18	0.08	120
81-mm M374A2	2.1	20	125	0.14	0.05	119
60-mm M49A3	0.43	12	25	0.05	0.03	118

Table 6 - Maximum Fragment Weight, Initial Fragment Velocity and Kinetic Energy for Five Tested Munitions

Munition	W_F, Maximum Fragment Weight, lb	V_F, Initial Fragment Velocity, ft/s	Kinetic Energy, 10^6 lb-ft^2/s^2
155-mm M107	0.467	4667	5.085
4.2-in M329A2	0.079	6391	1.613
105-mm M1	0.155	4870	1.868
81-mm M374A2	0.031	6721	0.700
60-mm M49A3	0.033	3605	0.214

As an example, for a shell such as the 3-in Stokes Mortar Round, the maximum fragment weight and initial fragment velocity are 0.0436 lb and 6189 ft/s, respectively. The resulting kinetic energy is 0.835 x 10^6 lb-ft^2/s^2. The next largest fragment kinetic energy in Table 6 is the 4.2-in M329A2 round. Therefore, a sandbag enclosure with a roof and wall thicknesses of 24 inches should be used to contain the fragments and suppress the blast overpressures. The maximum sandbag throw distance is 125 ft. Therefore, the withdrawal distance is 200 ft.

Based on this procedure, a more complete list of typical munitions is given in Table 7. This table includes the required sandbag wall and roof thicknesses and maximum expected sandbag throw distances to be used for each munition. For other munitions not listed in Table 7, the procedure given above can be used. The procedure should not be used to extrapolate sandbag thicknesses or sandbag throw distances for munitions larger than the 155-mm M107.

3.2 Enclosure Construction Method

The enclosure construction method follows the procedure that was used to build the test enclosures, with a few modifications. Figure 4 illustrates a typical enclosure. Figure 5 shows a photograph of a sandbag enclosure for an 81 mm mortar.

The sandbag fabric should be woven polypropylene. Each bag should have a nominal volume of 0.5 ft^3 and an approximate weight when full of 50 lb. The bags should be filled with washed sand, either dry or in saturated surface dry (that is, slightly moist) condition. Wet sand should not be used. Prefilled sandbags should be protected from the rain by storage on pallets, off the ground surface, and by covering them with a plastic tarpaulin or similar cover to prevent them from becoming saturated with water. The gradations and physical composition of the sand are not critical but it should be at least typical of local construction practice for sand used in foundations and backfill. Minor inclusions of clay or soils materials can be permitted. However, no rocks or stones should be placed in the sandbags. Typically, the sand used for the tests had a density of about 100 pounds per cubic foot and a moisture content of 6-7%.

Four walls of identical thickness should surround the munition. The minimum wall thickness should be the thickness determined using the procedure in Section 3.1 above. The sandbag walls should be stacked to maintain a clear standoff distance of 6 inches between the shell and the inside face of each wall. The interior face of each wall should be vertical but the exterior face can be built with a 1:6 slope (2" horizontal to 12" vertical). If a sloped outer face is used, the thickness of the wall, at the nominal "top" of the wall, 6 inches above the top of the munition, must be no less than the specified required thickness

The sandbags should be placed tightly against each other. All vertical joints should be staggered, so there is no clear line of sight from the munition to the exterior. As the wall is built, each new layer of sandbags should run in opposite direction to the layer below, so that the layers are interlocked (see Figure 6).

At a minimum, a double layer of sandbags shall be used. For example, when a 12" thickness is required, the sandbags should be oriented so that two sandbags are necessary to achieve this thickness (see Figure 7).

After the walls are constructed to a height of 6" above the upper surface of the munition, the shaped charge or other initiator should be placed on the shell. Ideally, the use of shaped charges, such as oil well perforators, is recommended. These add very little to the total charge weight for each detonation, given the highly directional nature of the effects of the shaped charge. Also, the use of shaped charges for initiation parallels test procedures. The shaped charge should be located either on top of the munition or on its side. If it is located on the side of the round, the charge should be tilted downward sufficiently to ensure that the shaped charge jet penetrates the round and is directed into the ground, rather than into the opposite sandbag wall. Generally, a small mound of sand next to the round can be used to establish this orientation.

A sheet of 3/4-inch thick Douglas Fir (or equivalent) plywood should be cut to the dimensions of the cavity between the walls, plus 12 inches in each direction. The plywood sheet is then centered on the walls so that it bears on 6" of each wall. The additional sandbags that make up the roof of the enclosure are then placed on top. As with the side walls, the roof sandbags should be stacked with staggered horizontal joints and alternating directions in each layer. The exterior sides of the roof may also be vertical or have a 1:6 slope. The thickness of the sandbag roof, above the plywood panel, must be the same as the required wall thickness.

After the sandbag layers of the roof have been placed to the correct height, the enclosure is complete and the munition may be detonated.

Table 7 - Required Wall and Roof Thicknesses for Sandbag Enclosures, with Expected Sandbag Throw Distances and Pressures, for Tested and Non-Tested Munitions

Munition	Charge Weight (lb)	W_F, Maximum Fragment Weight, lb	V_F, Initial Fragment Velocity, ft/s	Kinetic Energy, 10^6 lb-ft^2/s^2	Required Wall and Roof Sandbag Thickness, in	Expected Maximum Sandbag Throw Distance, ft	With-drawal Distance, ft
155mm M107*	15.48	0.467	4667	5.086	36	220	220
4.7-in Mark I	6.07	0.591	3566	3.761	36	220	220
105mm M1*	5.08	0.155	4870	1.840	24	135	200
4.2-in M329A2*	8.165	0.079	6391	1.607	24	125	200
4-in Stokes	7.92	0.078	6336	1.570	24	125	200
75mm M48	1.47	0.153	3471	0.922	24	125	200
3-in Stokes	2.1	0.044	6189	0.835	24	125	200
2.75-in M229 Rocket	4.8	0.050	5569	0.777	24	125	200
81mm M374*	2.1	0.031	6721	0.696	20	125	200
37mm MK II	0.53	0.030	5758	0.490	20	125	200
60mm M49A3*	0.42	0.024	5114	0.310	12	25	200
FMU 54A/B	0.357	0.006	9031	0.263	12	25	200
40mm MK2 Mod 0	0.187	0.033	3605	0.215	12	25	200
MK II Grenade	0.125	0.014	3425	0.083	12	25	200
25mm M792	0.096	0.005	5736	0.081	12	25	200
M67 Grenade	0.40625	0.001	7006	0.029	12	25	200
20mm M56A4	0.0264	0.0000011	4941	0.004	12	25	200

* = tested munitions

3.3 Withdrawal Zone

A withdrawal zone is necessary for any detonation. This withdrawal zone applies to everyone, both public and operational personnel. The withdrawal zone is the maximum of the sandbag throw distance, the distance to a sound level of 140 db, or 200 ft. For all munitions tested, the sound level at 100 ft was substantially less than 140 db. At 200 ft. the sound level will be even lower. The withdrawal zones are also listed in Table 7.

4.0 Summary and Conclusions

A test program has been performed to determine the effects of sandbag enclosures for mitigating fragments and blast effects due to an intentional detonation of a munition. A total of eighteen tests on five different munitions were performed. A summary of the test procedures and results are presented in this document.

The results of these tests have been used to develop guidelines for the use of sandbag enclosures to mitigate the fragments and blast effects due to an intentional detonation of a munition. Methods for determining the required sandbag thickness and the resulting sandbag throw distance are detailed in Section 3.0. Figures 4, 5, 6 and 7 show the resulting sandbag enclosures.

5.0 References

1. TM5-1300, "Structures to Resist the Effects of Accidental Explosions", Departments of the Army, the Navy, and the Air Force, November 1990.

2. HNC-ED-CS-S-98-1, "Methods for Predicting Primary Fragmentation Characteristics of Cased Explosives", M. Crull, U.S. Army Engineering and Support Center, Huntsville, January 1998.

3. "Evaluation of Sandbags for Fragment and Blast Mitigation", D. Stevens, Southwest Research Institute, San Antonio, TX, January 1998.

4. "User's Guide for Microcomputer Programs CONWEP and FUNPRO Applications of TM 5-855-1. "Fundamentals of Protective Design For Conventional Weapons"", Revision 2, D. Hyde, US Army Corps of Engineers Waterways Experiment Station, February 1989.

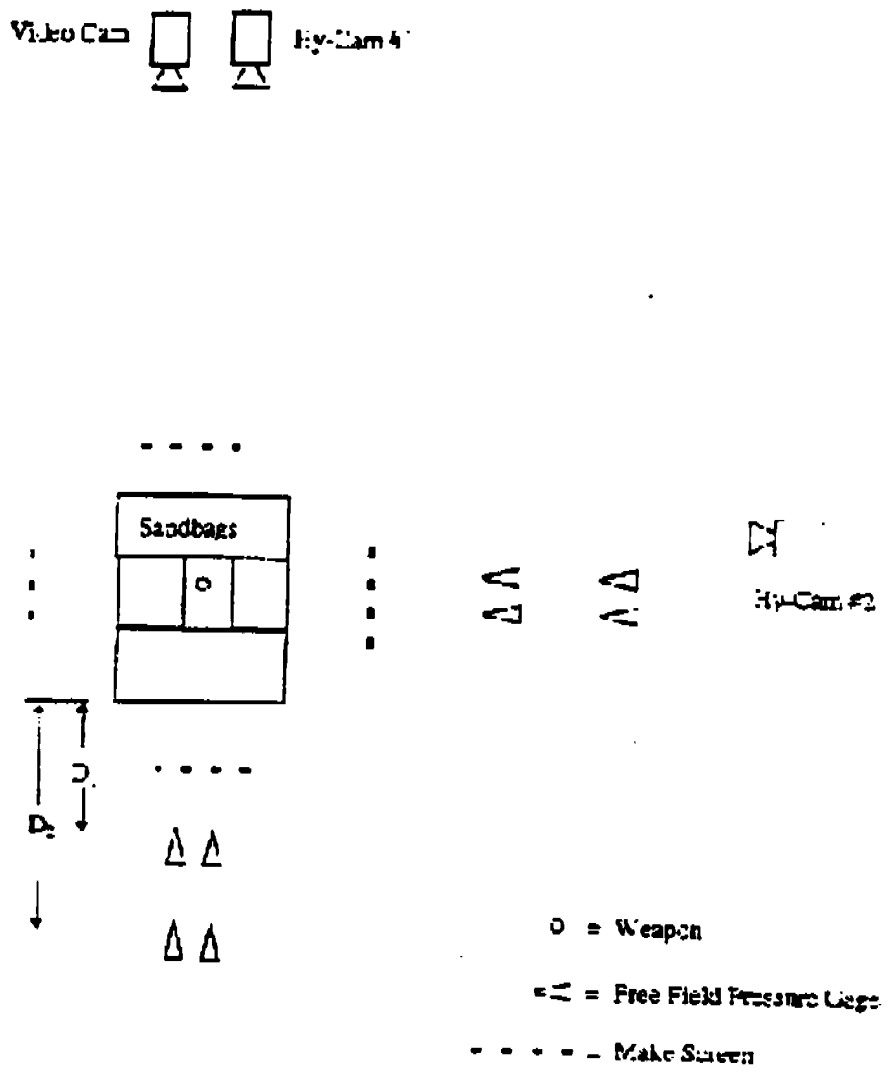
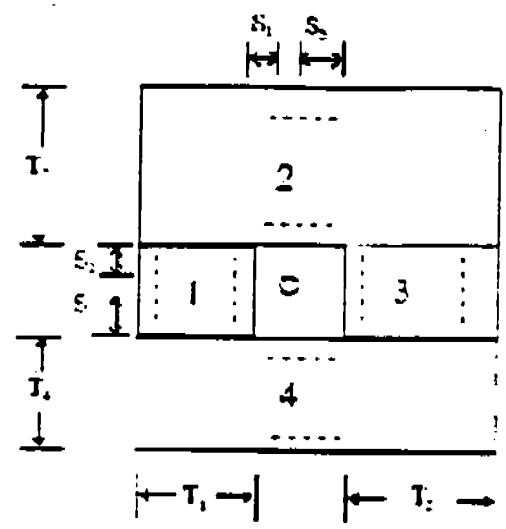
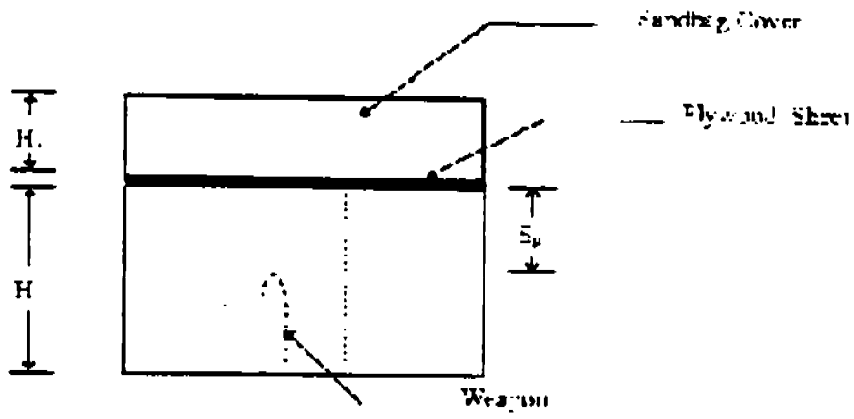


Figure 1 – Site Layout for Tests of Sandbag Enclosures



PLAN



ELEVATION

Figure 2 – Sandbag Enclosure Configuration for Vertical Weapon Tests

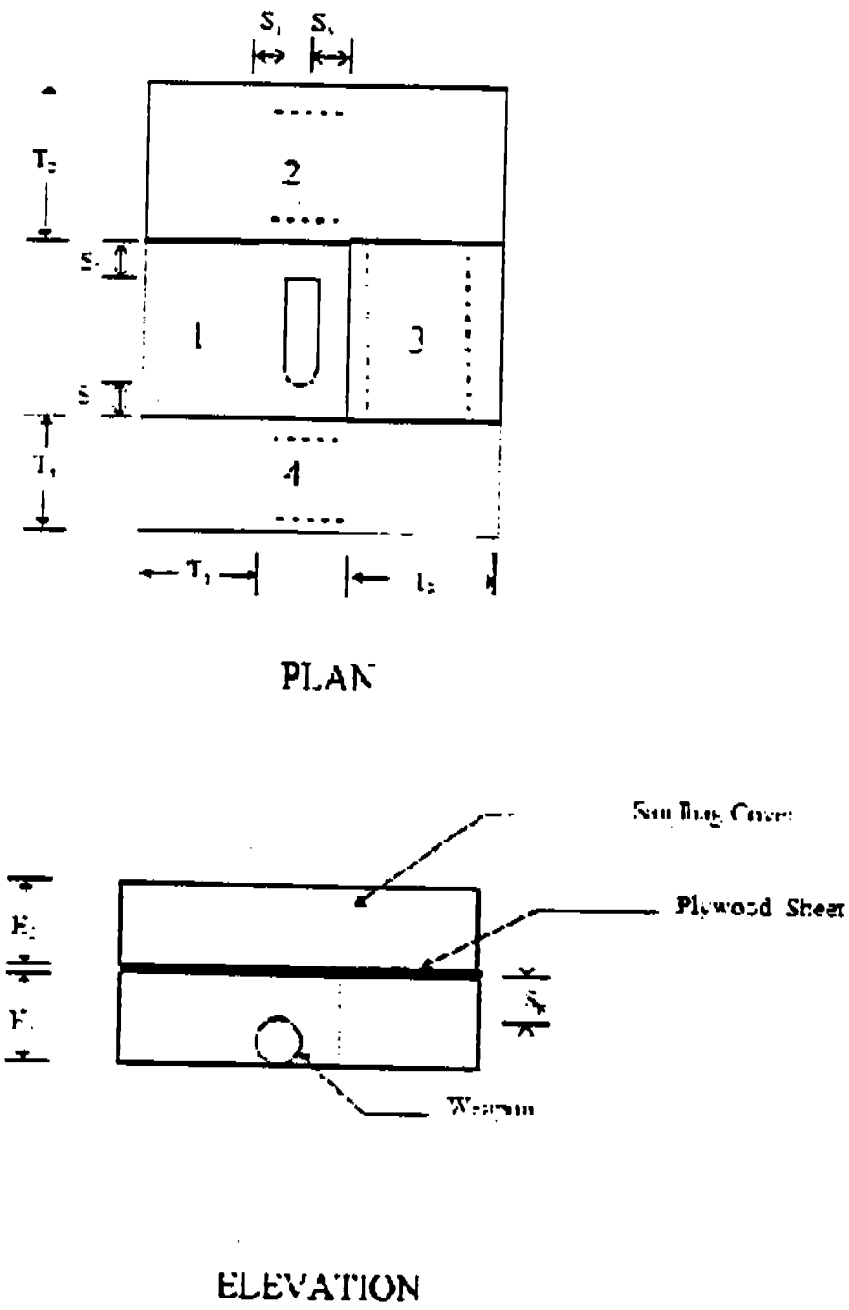
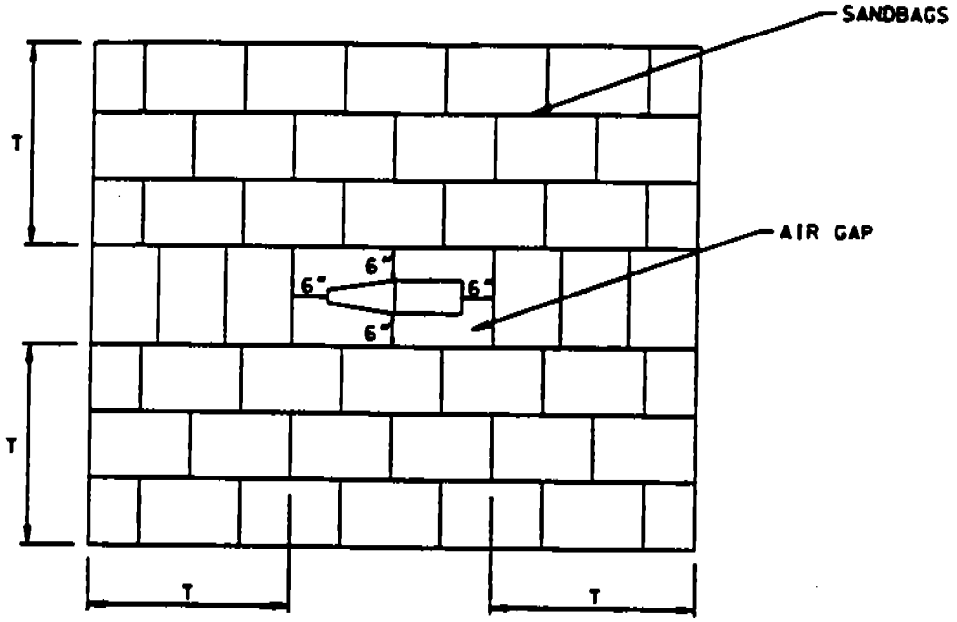
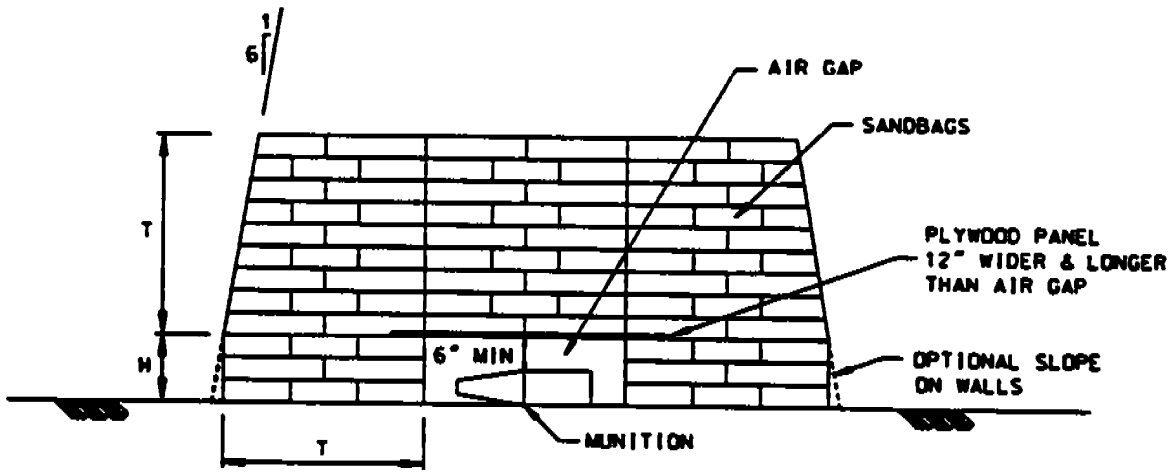


Figure 3 – Sandbag Enclosure Configuration for Horizontal Weapon Tests



T=THICKNESS OF SANDBAGS REQUIRED FOR SPECIFIC MUNITION

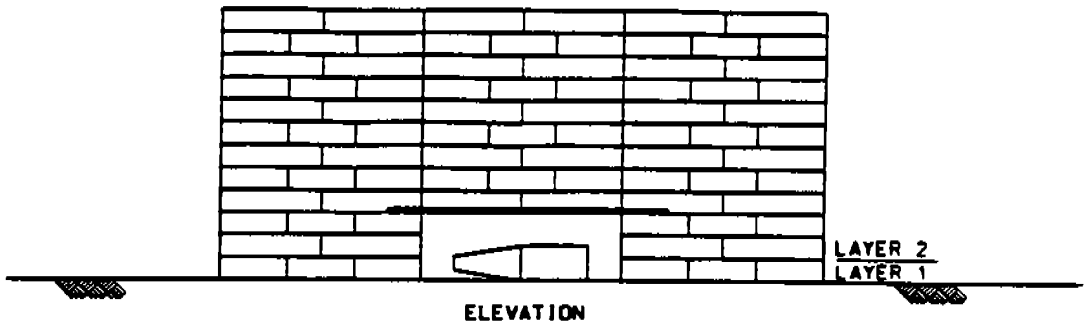
PLAN VIEW AT ELEVATION H
SANDBAG ENCLOSURE



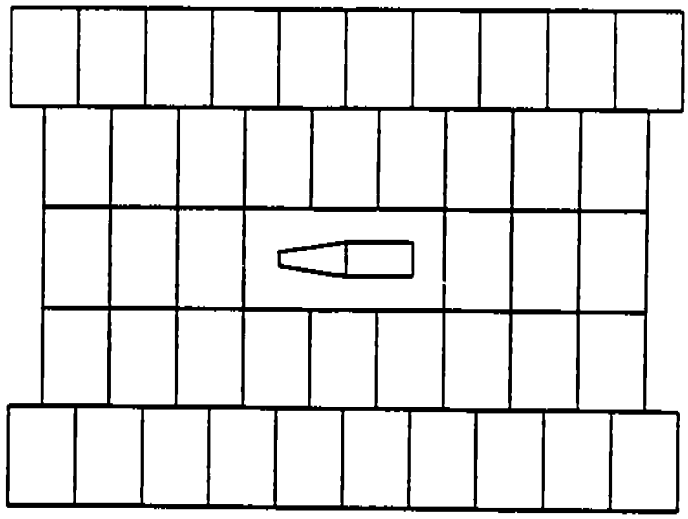
SIDE SECTION VIEW
SANDBAG ENCLOSURE

Figure 4 - Typical Sandbag Enclosure

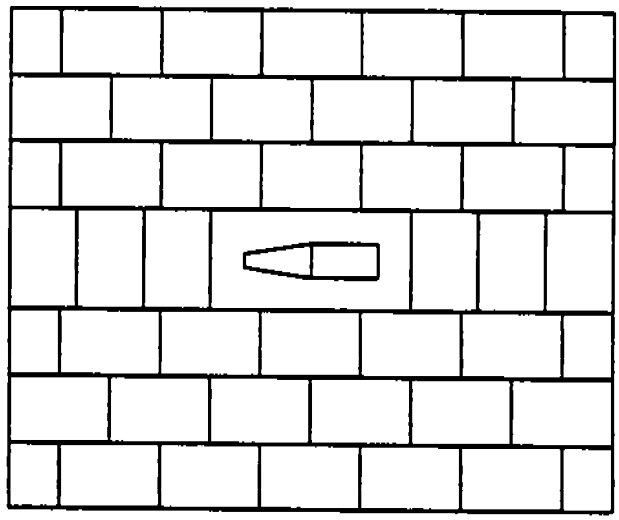
Figure 5 – Sandbag Enclosure for an 81 mm M374A2 mortar.



ELEVATION



LAYER 1



LAYER 2

Figure 6 - Interlocking Alternate Layers of Sandbags

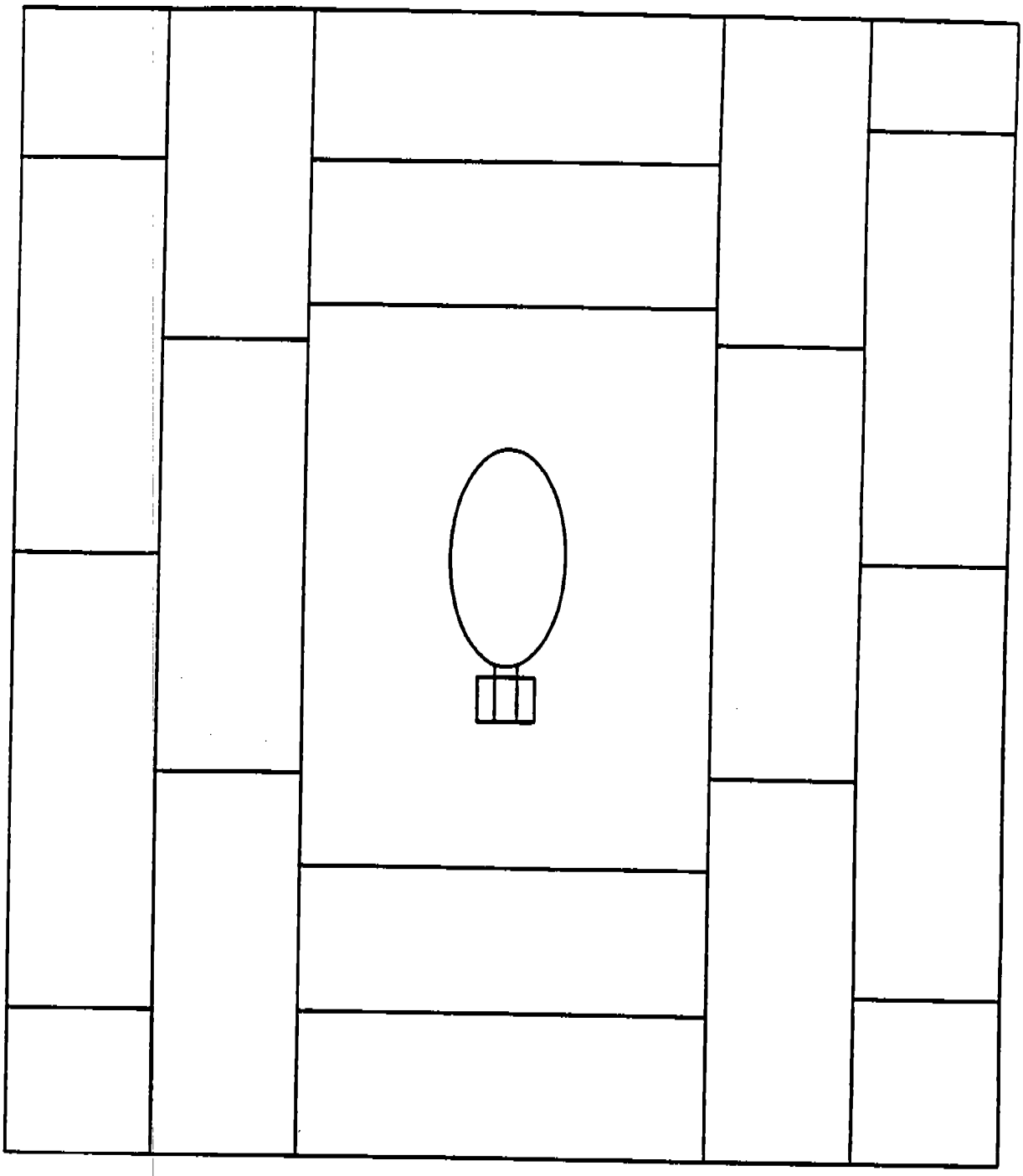


Figure 7 - Configuration for 12" Wall Enclosures

APPENDIX K

MTADS STANDARD OPERATING PROCEDURES

Geophysical Data Collection
Daily Log and QC Testing
MTADS EM Array

Date: _____

Blackhawk Field Personnel

_____ _____

_____ _____

GPS Base Station Setup

Base Location: _____

Frequency: _____ MHz

Time: _____

AM Standardization Tests

1) Warm up EM instrument for 15 minutes.

Start Time: _____

2) Collect data for at least 2 minutes in a static mode (not moving).

File Folder: _____ File Name: _____

Time: _____

4) Position Standard Board centered on coils.

(Enter coil readings in mV)

	LEFT	CENTER	RIGHT
Top			
Bottom			

5) Positional Accuracy Test
Collect data over standard line in 2 directions

File Folder: _____ File Name: _____

Data Collection

Area: _____

Instrument Operator: _____

Folder: _____ File: _____

Start Time: _____ End Time: _____

FIELD NOTES (site conditions, obstacles, unusual work stoppages, etc.):

Midday Procedure

1) Download *.DAT file from GPS Base Station and Rover 4700 Receivers

Base *.DAT File Name: _____

Receiver *.DAT File Name: _____

2) Erase *.DAT files from GPS Base Station and Rover 4700 Recievers

3) Restart GPS Base Station Time: _____

PM Standardization Tests

1) Collect data for at least 2 minutes:

File Folder: _____ File Name: _____

Time: _____

3) Position Standard Board centered on coils.

(Enter coil readings in mV)

	LEFT	CENTER	RIGHT
Top			
Bottom			

4) Positional Accuracy Test
Collect data over standard line in 2 directions

File Folder: _____ File Name: _____

Time: _____

/file name	(.extension)
/file type	raw, edited, processed data
/contractor name	name
/sensor	MTADS EM
/start date	mm/dd/yy
/end date	mm/dd/yy
/line spacing	(in feet)
/station interval	(in feet)
/line number	
/start station number	
/Sector designation	sector number
/data easting (origin)	state plane feet east
/data northing (origin)	state plane feet north
/survey reference system	(e.g., California State Plane, Zone 9, North American Datum 1983)
/channels (z)	4
/z1	(e.g., top channel in millivolts)
/z2	
/z3	
/z_n	
/comments	
/end	

Line 0

record	northing	easting	top	bottom	normalized	difference	time

FIELD OPERATIONS PLAN FOR MULTI-SENSOR TOWED ARRAY DETECTION SYSTEM (MTADS) ELECTROMAGNETIC (EM) ARRAY

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January 3, 2001

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1.0 INTRODUCTION

This document describes the field logistics and processing procedures for the Multi-sensor Towed Array Detection System Electromagnetic (MTADS EM) array. Surveys with this system are designed to identify both ferrous and non-ferrous metal objects. These metal objects may be unexploded ordnance (UXO) or UXO scrap.

2.0 GEOPHYSICAL EQUIPMENT

The MTADS EM array utilizes a modified version of the Geonics EM61 Time Domain Electromagnetic (TDEM) metal detectors. This system generates an EM pulse in the transmitter coils, which causes eddy currents to flow both within the ground and within metal objects. At approximately 300 microseconds after the energizing EM pulse has been terminated, the decay of the magnetic field from these eddy currents is measured with the EM61 receiver coils. At this time, most of the ground eddy currents have decayed to a low level and the majority of the remaining signal, if any, is from metal objects. This system is designed so that in many areas a low level and/or constant signal is received when no metal is present. When metal is present, an increased signal is received. This signal is generally highest, for larger objects, when the coils are located directly over the object. This results in "bulls-eye" type anomalies for isolated metal objects and simplifies data analysis.

In the EM array, three pairs of overlapping Geonics EM61 coils are contained in a fiberglass trailer. This trailer is towed with a custom designed low ferrous metal vehicle.

Positioning for the MTADS is accomplished with the Trimble 4700 RTK differential global positioning system (GPS). This system will provide positions in real time with centimeter level accuracy. The GPS antennae is located on the tow arm between the vehicle and the EM61 coils. The 4700 receiver is located within the tow vehicle and receives data from both the GPS antennae and from the GPS base station which is generally located within one to two miles, line of site, from the survey area. Positional data is recorded in WGS-84 latitude and longitude.

The geophysical data and positioning data are sent to a data acquisition computer within the tow vehicle. This data is stored on the hard disk of the computer for downloading at the end of the field day. In addition, positional/navigational data and geophysical sensor data is displayed in real time on the computer screen allowing the operator to monitor position and geophysical data quality.

3.0 GEOPHYSICAL SURVEY PROCEDURES

3.1 Setup

Prior to starting fieldwork at the site, Blackhawk personnel will attend a project Health and Safety meeting. Short daily briefings will be given prior to each day's fieldwork.

The proposed geophysical area will be investigated to determine the best approach to data collection at the site. Obstacles such as fences, drainages, and hills will be accounted for in laying out the survey. The nearest survey control points will be investigated as to suitability as GPS base stations. If radio-modem coverage of the survey site is not possible from the survey control sites utilizing base and repeater transmitters additional survey control will be established.

3.2 Survey Equipment Parameters

The survey the data acquisition parameters will be:

EM61 Data Acquisition Rate	16 Hz
GPS Data Acquisition Rate	5 Hz
Survey Line Spacing	5 ft to 6 ft
EM61 Coil Height (Bottom Coil to Ground)	40 cm
EM61 Coil Separation (Vertical – Bottom to Top)	40 cm
Maximum Data Acquisition Speed (Tow Vehicle Max)	6 mph
Maximum Data Point Spacing (Along Survey Line)	0.55 ft

3.3 Daily Field Procedures

The EM MTADS daily fieldwork routine will consist of the following:

1) Attend morning Health and Safety meeting.
2) Setup GPS base station.
3) Check all fluid and battery levels in MTADS.
4) Drive to survey site.
5) Check GPS base reception.
6) Zero the EM61 coils over metal free ground.
7) Set metal standard on coils. Record values in daily log book.
8) If standard readings acceptable, collect EM61 data over survey site. Repeat last line of previous day.
9) Monitor GPS and sensor data during acquisition.
10) Start new data file every hour to hour and one half. Record file names, approximate area of coverage, start and stop times, and general operating conditions in daily logbook.

4.0 DATA PROCESSING

The MTADS Data Analysis System (DAS) will be used to analyze the EM geophysical data collected. The DAS allows editing and processing of both the GPS and EM61sensor data. The positional data and sensor data are merged within the DAS. The merging of the data accounts for differences in sensor positions and the time lag between GPS and EM61 data streams. An autopicker will be utilized to identify locations and areal extent of target anomalies. The autopicker requires a minimum threshold value to utilize in the identification of targets. The threshold value is typically determined from the results of prove-out surveys and is dependent upon the expected sized and depth of the expected ordnance. The picked targets will then be modeled by the DAS. In the modeling process, it is assumed the metal object can be approximated by a sphere. The modeling output includes improved x and y location of target center, approximate depth to center of target and approximate equivalent radius of the target. This list will be delivered both in a hard copy and electronic format.

The positional data is collected by MTADS in WGS-84 latitude and longitude. The DAS will convert the positional data to the local State Plane coordinate system. All target lists and maps will be output in the local State Plane coordinate system.

In addition to target lists, the DAS will output processed data files covering the survey area. This data will be color gridded utilizing the Geosoft® Oasis software and plotted on hard copy maps.

The data processor will be responsible for preparing Daily Work Record. This record will show:

1) Project Number and Name
2) Blackhawk Personnel on site and their duties.
3) Geophysical mapping times for the day and approximate acreage covered.
4) Any unusual work stoppages.
5) Site conditions, data collected and general remarks on survey.

5.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The geophysical and positional data stream is checked periodically to ensure the highest quality data is being collected. These data checks are performed at various stages during data collection and processing.

The positional data is obtained from a GPS RTK system. This system requires a minimum of five satellites to be detected to initialize the system and obtain centimeter positioning. Utilizing available GPS system software, a predication of satellite availability for up to two weeks in advance can be made. With this information, times of poor satellite coverage for the survey site are identified and data collection will be suspended during low satellite coverage.

The GPS data quality is also monitored during data acquisition. A real time display of both GPS and EM61 data is shown on a computer screen within the tow vehicle. A GPS data quality index number is also displayed. These numbers are:

0 – No satellites are detected by GPS receiver.

1 – Satellites detected by receiver but no correction being received from base station. Positional accuracy is sub 100 meters.

2 – Float solution of GPS data. Positional accuracy is sub-decimeter.

3 – Fixed solution of GPS data. Positional accuracy is centimeter level.

4 – Differential GPS solution. Positional accuracy is sub-meter.

A quality index of 3 is normal for data collection. Data can be collected for short periods at an index of 2. Data collection is stopped if an index of 4 persists for more than 30 seconds. Data collection immediately stops if an index of 0 or 1 occurs.

The quality of EM61 data is also consistently monitored. Prior to beginning data collection, a "clean" (metal free) area is located and the six coils are "zeroed." A metal standard is then placed on the coils and a reading for each coil is taken. A second reading is taken at the end of the data collection day. These readings are recorded in the field book and should be within 20% of the average of all the standard readings.

The equipment operator monitors the EM61 data in real-time from all six coils on electronic strip charts, which scroll as the data is collected. Most data problems can be identified in the data display and steps taken to remedy them.

In the processing of the data with the DAS, both the raw and processed GPS and EM61 data are reviewed and checked for data quality. The GPS index numbers are recorded with the data and are rechecked during the processing. The EM61 data is also checked and poor quality data rejected.

6.0 PRODUCTION AND DELIVERABLES SCHEDULE

Fieldwork is expected to be done on a six- day, ten-hour/day work week schedule. Blackhawk will utilize a crew of three to collect and process the geophysical data. Anticipated field production is expected to be about ten to twelve acres per day. This productivity rate may be significantly lower in areas with difficult terrain. The collected raw data will be delivered within 36 hours of collection. Processed data and dig sheets will be delivered within three working days for those sites with up to 200 targets per acre. QC data will be delivered within one working day.

Naval Research Laboratory

Washington, DC 20375-5320 NRL/PU/6110–01-434

Man-Portable Adjuncts for the *MTADS*

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Man-Portable Adjuncts for the *MTADS*

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1. Introduction

1.1 Background

The U.S. Army Corps of Engineers – Huntsville (USACOE) estimates that approximately 20 million acres of land are contaminated with unexploded ordnance (UXO) or ordnance explosive waste (OEW) within the continental US. This is the result of a variety of operations including training, testing, manufacture, storage, disposal and intentional burials. Now, either through congressional mandates such as the formally used defense sites (FUDS), base realignment and closure (BRAC) or state litigation, these sites must be evaluated, remediated, as required, and certified as safe for the intended ultimate public use. This is a very slow and costly process, and in some cases, impossible to do with existing technologies and resources.

The Environmental Security Technology Certification Program (ESTCP) has the goal of its UXO Cleanup Thrust developing automated, more economical, and more efficient methods to accomplish UXO site cleanups through the demonstration and fielding of new technologies. One of these funded programs was the Multi-sensor Towed Array Detection System (*MTADS*) developed by the Naval Research Laboratory.[1] This system consists of a tow vehicle, two low self-signature tow platforms; one for an eight sensor magnetometer array, the other for a three sensor time domain electromagnetic (EM) pulsed induction array. *MTADS* uses GPS for navigation, sensor position locations, and survey guidance, and a sophisticated data analysis system for interpreting the field data. Analysis produces target reports and a variety of graphics products. The target analyses include target positions, depths, and orientations. In addition, predicted target size and a "goodness of fit" value show how well the target can be represented by a dipole model.[2] This system was demonstrated for ESTCP at the NRL's Chesapeake Bay Detachment at Chesapeake Beach, MD in October 1996;[3] at the Marine Corps Air Ground Combat Center, Twentynine Palms, CA[4] in December 1996, and at the Jefferson Proving Grounds, Madison, IN in January 1997.[5] Additionally, the *MTADS* was successfully demonstrated on the Badlands Bombing Range, on the Pine Ridge Reservation, in South Dakota in July 1997;[6] at the former Fort Pierce Naval Amphibious Base, Vero Beach, FL in January 1998;[7] the former Buckley Field, Aurora, CO in June 1998;[8] the Laguna Pueblo Reservation in New Mexico in July 1998;[9] at the Portsmouth Naval Shipyard, in Kittery, ME in October 1998;[10] at the JPG IV Data Fusion Demonstration, in October 1998;[11] and at the Walker River Reservation, in Nevada[12] in November 1998. Based on the success of these field demonstrations NRL signed a CRADA with a commercial company, and a non-government system has been designed and built based on the NRL *MTADS*. It is currently available for commercial use.[13]

The USACOE has recently estimated that vehicle towed-array survey systems can be used effectively on only about 30% of the UXO-contaminated land because of rugged terrain, buildings on or near the site to be surveyed, or wooded sites. GPS navigation systems do not operate effectively without a clear view of the sky, limiting the use of systems like *MTADS* under forest canopies. ESTCP funded NRL to develop an *MTADS* man-portable magnetometer system (MMS) in FY 98 and a man-portable EM system (EMMS) in FY 99. Each of the systems is being implemented with both GPS and a new acoustic navigation technology to allow surveying in areas without sky view. The system hardware designs have been carefully planned to allow MMS and EMMS data to be incorporated with vehicular survey data. This has required implementation of a new data acquisition system for both the vehicular and the man-portable systems and modification of the data analysis system (DAS) to incorporate and seamlessly overlay all data sets.[14]

In conjunction with this program, and other ESTCP and SERDP UXO programs being managed by NRL, a new ordnance test range was established at the Blossom Point facility of the Army Research Laboratory. This is the depot site for the *MTADS* and supports on-going development activities for the *MTADS* system that take place outside the laboratory environment. The test site, known as the Magnetic Test Range, is described in a separate document.[15] The Magnetic Test Range was very important for benchmark testing of the Man-Portable systems during their development, and has served for test and evaluations of numerous other systems being developed by SERDP and ESTCP by other organizations.

In August 1999 the Man-Portable systems were evaluated in a demonstration at the L Range at Blossom Point, MD. This demonstration, described in the Technology Demonstration Plan,[16] was conducted jointly with another SERDP program demonstration.[17] The results of the L Range demonstration revealed some development short-comings of the Man-Portable systems. The results of the L-Range Demonstration have been documented[18] and will be further discussed in the body of this report. The L-Range demonstration led to a final year of development and refinement of the Man-Portable systems and a final demonstration of both adjunct systems at the Jefferson Proving Ground[19] in August 2000.

1.2 Official DoD Requirements Statement

The Navy Tri-Service Environmental Quality Research Development Test and Evaluation Strategic Plan specifically addresses under Thrust Requirements 1.A.1 and 1.A.2, the requirements for improved detection, location and removal of UXO on land and under water. The index numbers associated with these requirements are 1.I.4.e and 1.III.2.f. The priority 1 rankings of these requirements indicate that they address existing statutory requirements, executive orders or significant health and safety issues. Specifically the requirements document states:

> *There are more than twenty million acres of bombing and target ranges under DOD control. Of particular concern for the Navy are the many underwater sites which have yet to be characterized. Each year a significant fraction (200,000-500,000 acres) of these spaces are returned to civilian (Private or Commercial) use. All these areas must be surveyed for buried ordnance and other hazardous materials, rendered certified and safe for the intended end use. This is an extremely labor intensive and expensive process, with*

costs often far exceeding the value of the land.... Improved technologies for locating, identifying and marking ordnance items must be developed to address all types of terrain, such as open fields, wooded areas, rugged inaccessible areas, and underwater sites.[20]

The *MTADS* addresses all aspects of the Tri-Service Requirements for land-based buried UXO. It is designed to rapidly and efficiently survey large sites, with commensurate economic benefits. Moreover, it is capable of detecting all classes of buried UXO at their maximum likely penetration depths. The system will correctly locate buried targets, determine their burial depths, classify the likely ordnance size, and provide for future target way pointing, as well as create GIS-compatible target output maps and sorted target tables. The man-portable adjuncts described in this document were designed to allow this capability to be extended into areas of rugged terrain and areas with poor sky visibility.[14]

1.2.1 How the Requirements Were Addressed Since there are many common components between the MMS and the EMMS, they were developed under a single program management plan. System performance specifications were developed that we felt would provide acceptable performance for instruments that could be used in commercial service. The performance specifications are documented in Table 1.

1.3 Objectives of the Demonstration

The great strengths of the *MTADS* are its sensitivity which allows detection of all ordnance to its maximum self burial depths, the position location accuracy of the navigation and positioning system, and the target analysis algorithms which allow location of buried objects to within the actual ordnance volume, and the analysis output products which provide for the efficient reacquisition and remediation of the targets. It was a design goal for the man-portable projects to preserve the detection sensitivity for buried ordnance while extending the survey capability to include rugged terrain and open forest areas. Furthermore, new hardware and software were developed and the existing DAQ and DAS capabilities have been modified to allow integration of vehicular and man-portable data for simultaneous analysis with a single analysis software utility. The projects described in this report were designed to demonstrate these objectives.[14]

A secondary objective of the program is to transition the technology to the commercial sector. A CRADA was signed with Blackhawk Geometrics to create a commercial version of the NRL *MTADS* vehicular system.[21] This system currently exists and is providing services to the government on former ranges. A separate phase of the CRADA contains provisions for joint development and transition of the man-portable adjuncts being demonstrated here. Therefore, transition of the man-portable adjunct technology is assured. CRADA funds, in part, supported the developments described in this document.

Table 1. System Specifications and Requirements for the *MTADS* Man-Portable Adjuncts.

System Specification/Requirement	MMS	EMMS
Continuous Operating Time	2 hours	2 hours
Survey Area (Single Setup)	1 Acre	1 Acre
Lane Spacing	0.5 m	0.5 or 1.0 m
Sensor Sensitivity	0.1 nT (same as vehicular *MTADS*)	Scalable to vehicular *MTADS*
Sensor Data Rate	10 Hz	10 Hz
Navigation Data Rate	GPS/5 Hz. Acoustic/1 Hz	GPS/5 Hz. Acoustic/1 Hz
Sensor Position Accuracy	GPS 0.1 m. Acoustic 0.25 m	Same as MMS
Sensor height above ground	0.25 m (fixed)	0.25 m (fixed)
DAQ	Compatible with vehicular DAQ based on modified Geometrics 858 data recorder	Same data recorder as the MMS
DAS	Seamless integration with vehicular data	Same as MMS

1.4 Regulatory Issues

There are no regulatory issues unique to the man-portable *MTADS* adjuncts. The primary challenge is to gain the recognition and approval of the Army Corps of Engineers for these technologies so that future RFPs for UXO range projects will be written in a manner that will either sanction these technologies, or at least allow their inclusion in proposals for site work.

2.0 Technology Description

2.1 Background and Applications

Since there are many common components between the MMS and the EMMS, as mentioned above, they were developed under a single program management plan. The primary platform for each sensor involves a wheeled cart. This approach, we feel, provides for the smoothest operation, allows coordinated deployment of all sensor and navigation hardware during surveys, and maintains the sensors at a fixed height above the ground. The sensor dimensions and the array design were limited to the width of a person's shoulders based upon the premise that the system should be deployable in areas where a person could easily walk. An exception was made for the EM sensor, as described below.

2.2 System Component Descriptions (For the L Range Demonstration)[22]

2.2.1 Sensors The magnetometer sensors chosen for the MMS are Geometrics 858 ROV Cesium Vapor magnetometers, identical to those on the *MTADS* vehicular system. New EM sensors were developed with Geonics, Inc for this project. A 1m X 1m coil system was purchased which had the same performance characteristics as the individual EM units on the vehicular array. A second coil system was ordered with dimensions of 0.5 X 1.0 m. This system was designed so that the wheels could be mounted either along the short or the long coil dimensions. This allowed the system to be used as a 0.5 m wide instrument in tight or confined spaces or as a 1.0 m wide system in more open applications. The sensitivity of the 0.5 m coil system was supposed to be increased by addition of additional turns in the transmit coil. An initial demonstration was conducted at the L-Range (a mortar and fuze test site) at Blossom Point, MD. Based upon a disappointing performance in the L-Range demonstration the EM coil was subsequently replaced with a new 0.5 X 1.0 m instrument which replaced both the older coils. This new system is described in Section 6 of this document.

2.2.2 Platforms Both the MMS and the EMMS are intended to be operated primarily with the sensors mounted on two-wheeled carts. The sensors and the navigation antennas are mounted on the cart. Batteries and navigation hardware are mounted in a specially designed backpack worn by the operator. Several concept designs were assembled from PVC tubing and other plastic components until a preliminary design was fixed. At this point a prototype magnetometer cart was designed and procured from a plastics fabricator. The prototype MMS survey system is shown in Figure 1 operating with the GPS navigation system. Subsequent to the L Range Demonstration, the MMS was completely redesigned. The redesigned system is described in Section 6.

Figure 1. The MMS prototype system deployed at the L-Range Demonstration.

The commercial Geonics EM-61 coils are delivered with a two wheeled transport system. This design, as shown in Figure 2, was used for the prototype instruments. Either the 0.5 X 1.0 m or the 1.0 X 1.0 m coils were designed to be usable as a single cart. The cart and antenna support system is designed to rigidly hold both the top and bottom coils in place, with the GPS or acoustic antenna mounted centered above the

Figure 2. The EMMS prototype system deployed at the L-Range Demonstration.

upper coil. Rigidity is required because the GPS antenna has a significant signal at the upper coil which must be nulled as part of data preprocessing. Because of the excessive weight of the system batteries and the GPS instrumentation, the equipment was split between two backpacks for the L Range demonstration, as shown in Figure 2. When using the acoustic navigation system all equipment was accommodated in a single backpack and only a single operator was required to take survey data. As a result of the demonstration at the L Range, the EMMS was replaced by a new instrument as described in Section 6.

2.2.3 DAQ The backbone of the Man-portable survey equipment is the modified Geometrics 858 data recorder, Figure 3. The standard Model 858 commercial system is configured with dual cesium vapor sensors, which can be used as two separate magnetometers or in a gradiometric configuration. The off-the-shelf 858 also comes with one RS-232 COM port access to the palm-top data storage device. Two battery packs are included with an operating time of six hours each. The data logger stores 2.5 Mb of data or about 4.5 hours in the MMS configuration in which the GPS is recorded at 5 Hz and the sensors at 10 Hz, in up to five separate files. The single COM port provided with the standard unit is suitable for GPS or manual input of ASCII text.

The Model 858, modified for use with the MMS and the EMMS, incorporates three more COM ports to accommodate the additional data inputs needed for the MMS. These COM ports are included in the 858 battery (9 pin) connector. The original COM port, located in the data out/GPS connector (8 pin), is called COM Port 1. The first port in the battery connector is called Port 2 and in the MMS is used for the GPS GGK string input at 5 Hz. Port 3 is used to input the 1Hz acoustic navigation data from the USRADS Data Pack. Port 4 is used to input the 1 pulse per second from the Trimble 7400 receiver or the sync pulse from the acoustic navigation system. The system software has been modified to trigger the data stream from the EM61 through COM ports.

When the MMS is deployed with GPS navigation, all data are recorded on the 858; the 2 mag sensors, the 5 Hz GGK string from the Trimble 7400 (PWR I/O 1) and the 1 PPS (Aux port). All data are downloaded through COM Port 1 in binary format. When the MMS is deployed with the USRADS acoustic navigation system, the record number generated by the transmitter is recorded in the 858 *via* COM port 3 along with the sync pulse through the 858 COM port 4. Positions (tagged with the record number) are derived at the remote site and combined in the DAS. The Geometrics data logger can either be mounted on sensor platform as shown in Figure 3, or can be worn in a "fanny pack" on the waist of the operator as shown in Figure 2.

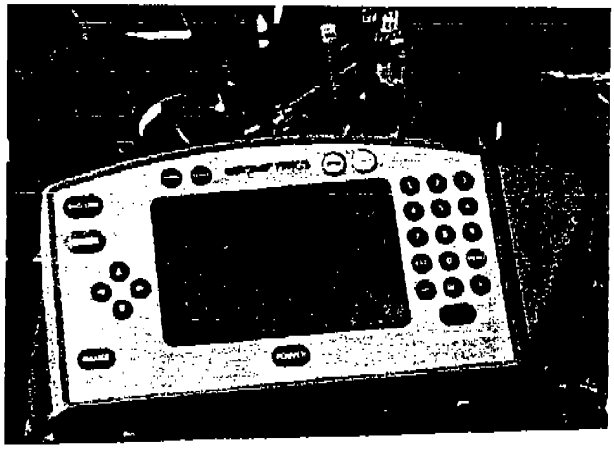

Figure 3. The Geometrics Model 858 data logger serves as the DAQ for both the MMS and the EMMS deployed with either the GPS or acoustic navigation systems.

2.2.4 Navigation Trimble Model 7400 GPS receivers, currently used by the vehicular *MTADS*, were used for the primary MMS demonstration at the L Range. This system,

operating with a Model 4000 SSI base station receiver, provides the full range of GPS location options. In the highest precision fix, RTK, (level 3, Real-Time Kinematic) the base station provides a differential position fix with fully resolved numerical ambiguities. This real-time location accuracy is 2-5 cm. A level 2 fix, (Float) is accurate to 10-50 cm because some of the integer ambiguities remained unresolved in the solution. The traditional differential solution (level 4) may have an accuracy degraded to 0.5-1.0 m. depending upon the number and position of the satellites in the solution. MTADS surveys are begun only with a level 3 fix. If during the survey the fix quality briefly drops to level 2, offsets and corrections are implemented in the data cleanup process. Survey data based upon lower quality fixes are typically not used in *MTADS* surveys.

The navigation fix quality can be observed only by using the chat mode during setup. If the GPS fix quality drops below float during a survey, the operator is not informed. For the L- Range demonstration using the Trimble satellite planner allowed us to avoid poor survey times. However, this approach was deemed unacceptable because the potential exists for collecting unusable data. The display and readout options were subsequently improved, as described in Section 6.

The Chemrad Navigation System (USRADS Model 2300) provides acoustic navigation data when satellite visibility will not support GPS navigation. This system deploys an acoustic transmitter on the rover platform and a network of up to ten transponders at fixed stations about the perimeter of a survey site. The system uses time-of-flight data to triangulate among all possible pairs of transponders to create a location position which is updated at 10 Hz. Evaluation testing in wooded areas has demonstrated that the USRADS System provides navigational fixes which are accurate to ~25 cm when 10 stationary receivers (S/R) are used to enclose a one acre wooded site. Under good conditions the acoustic sensors have a range of about 200 ft. This accuracy is degraded in high wind or high noise environments or when visibility is limited by obstructions. Deployment strategies are critical for successful use of this system. See the further discussion below and in Section 5.2.4 about limitations and potential improvements of the system.

2.2.5 DAS The *MTADS* Data Analysis System (DAS) has been modified to accept the data from the MMS and is fully integrated to merge the vehicular and MMS data, or multiple MMS data sets and provide the same analysis capabilities. Once preprocessing steps have been carried out, magnetometry data from the MMS or the vehicular system (using either navigation system with the MMS) can be combined into single survey data sets. For instance, wooded areas within a larger vehicular survey area, would be completed with the MMS (and acoustic nav) and edited to fill in missed areas in the vehicular survey. In general, data from multiple surveys of the same areas are not commingled, the better data would be used for any given area.

The identical approach is not used for data taken with the EMMS. Because of the different sensitivities of the various EM coil systems, and the various deployment options, a decision was made to process EMMS data separately from vehicular EM data. The baseline *MTADS* DAS currently has all necessary utilities, routines, and switches to allow processing of data from all vehicular and man-portable setups regardless of the navigation system used to survey.

2.3 Advantages and Limitations of the Technology

The MMS and EMMS were designed to allow the *MTADS* survey capability to be extended into rugged terrain that cannot be traversed by the tow vehicle. The addition of the acoustic navigation system allows the survey capability to be extended into areas that have limited sky view, including under forest canopies. The wheeled MMS cart is designed to be pushed ahead of the operator allowing him to maneuver through fairly tight spaces. The width of the cart and sensor arrays are designed to be at or below the width of the operator's shoulders. The wider EM coils are available for areas with less severe space constrictions.

Maintaining the sensors on the carts allows for smoother operation, minimizing motion-coupled noise and errors from uncontrolled swinging motions typical of sensors mounted on a hand-held boom. On the carts a fixed relative position of the sensors with the navigation antennas is maintained. A disadvantage of this design is that access is precluded from areas that are very tight and from areas that have difficult ground cover such as brush, deep mud, or extremely rugged terrain.

2.3.1 System Limitations The MMS and the EMMS were demonstrated on the L Range at the Army Research Laboratory during the week of 13 September 1999. Part of the site was in the open near a tree line. The remainder of the site was in the woods where the acoustic system was exclusively used for navigation. In open areas duplicate surveys were conducted with each navigation system. In the MMS surveys the location accuracies and the detection sensitivity levels were comparable to the *MTADS* towed array system with the GPS navigation system. Sensor location accuracy was lower when using the acoustic navigation system. These results are described more fully in Section 5.2.3 of this report.

In conducting EMMS surveys on the L-Range, we noted that the lower sensitivity of the 0.5m X 1.0m coils significantly degraded the system performance of the EM adjunct relative to the vehicular EM array. As deployed on the L-Range, the EMMS trailing behind the operator, is unstable and side-to-side rocking motions on rough ground produced location inaccuracies because of antenna displacement. The EMMS was relatively difficult to navigate in the woods because it trails behind the operator and is side-to-side unstable. It is difficult to maneuver through close areas because the operator cannot see when the coils or the wheels are becoming entangled in brush or going to be trapped by trees.

In addition, we identified several areas in which improvements could increase the ruggedness, reliability or long-term usability of the adjunct systems. Overall, following the L Range Demonstration, we concluded that while the adjuncts met most of the design performance specifications, they were unsuitable in their present configurations for use as commercial field instruments. We undertook numerous upgrades and modifications during FY-2000, the third year of the program, in preparation for the final demonstration. These modifications are outlined in more detail in Section 6.

2.3.2 Post Prototype Modifications The GPS navigation system, the backpacks, the cabling, the data acquisition system, and the sensor platforms were modified for both the MMS and the EMMS before the L-Range Demonstration. In addition the EM sensor for the EMMS was redesigned and the DAS was modified to process data from the new instrument. These developments are fully described in Section 6 of this report.

3.0 Pre-Demonstration Activities at the L-Range

3.1 Site Selection

Because there were limited funds available within the Man-Portable Program to support extensive demonstrations, alternatives were sought that would minimize expenses associated with transporting equipment and complex logistics support. Because compatibility of the MMS and EMMS with the vehicular survey data is an important objective, it is important that vehicular surveys be able to overlay the data taken using the man-portable adjuncts. Vehicular survey data of demonstration areas should serve as the benchmark against which the Man-Portable data is measured.

There are extensive impact ranges at Blossom Point that have been used for fuze development and testing using mortars and rockets. Some of these areas have been partially cleaned, most have not. Our setup of the Ordnance Detection/Classification Test Field clearly demonstrated that even areas not formally associated with known ranges, are also UXO contaminated.[15]

We chose an area at the ARL, Blossom Point facility for the Man-Portable Demonstration Site. The demonstration area was set up to be partially contiguous with areas selected for the ESTCP "EM and Magnetic Sensor Fusion for Enhanced UXO Target Classification" Demonstration scheduled for August 1999.[18] A part of the L-Range is shown in an aerial photograph in Figure 4. This area has long been a test range for various munitions. It is 800-ft wide by 5000-ft long, encompassing about 95 acres. The range is bordered on the south (river side) by a mixed pine and hardwood forest. The range itself is generally flat, grass covered, and is regularly mowed. The forest bordering the range varies from open woods to rugged areas with extensive underbrush. The 3-acre area designated for the ESTCP Data Fusion Demonstration is shown outlined in yellow. The MMS and EMMS demonstration areas are shown outlined in red. The entire area within the red boundary was surveyed with the EMMS and MMS platforms using the acoustic navigation system. The portion of the site accessible for use of the GPS navigation system was similarly surveyed with each portable system. The entire area within the yellow boundary was surveyed with both the magnetometer and EM *MTADS* vehicular arrays. The activities are described in the Technology Demonstration Plan[16] which is included as Appendix B on CD-ROM.

3.2 L-Range Predemonstration Sampling

Human Factors Applications, Inc., conducted an ordnance removal project at the Blossom Point Test Facility in November 1996.[23] Two areas were cleared bordering the west and north

Figure 4. The L-Range at Blossom Point. The approximate area of the *MTADS* Data Fusion Survey is outlined in yellow, the Man-Portable survey area is outlined in red.

sides of the L-Range. The objective of these projects was the survey and removal of ordnance allowing construction and installation of power lines. The "Mag and Flag" remediation operation used Schonstedt Gradiometers. During the remediation, 753 live UXO items and 9,267 lbs of OE and other scrap were recovered. The surveyed areas included 36 acres of open land and 30 acres of woodlands. **Table 2** lists the live ordnance recovered. This list of ordnance represents a cross section of the items which we expected to recover from the surveys and digging associated with our demonstrations.

3.3 L-Range Predemonstration Shakedown Tests

The man portable platforms have been continuously tested during the development phase of the project against individual items in the test pit and against the NRL Ordnance Detection/Classification Test Field at Blossom Point. Because it is an objective of the program that the MMS and EMMS data seamlessly overlay with data from the vehicular system, we took benchmark surveys of the Test Field using the vehicular magnetometer and EM arrays. The magnetic test range and classification test field have been described in detail in earlier NRL publications.[15] Numerous other technologies have also been tested and demonstrated at this test site, including the Geophex, GEM 3, the Geonics EM-63 (by NAEVA), the Geonics EM-61 3D (by

Blackhawk Geometrics), an R&D time-domain instrument (by Johns Hopkins APL) and an R&D GPR system (by Ohio State/CRELL).

3.4 Site Preparation

The entire L-Range was surveyed using the vehicular *MTADS* magnetometer array. Areas, shown in Figure 4 were carefully chosen to assure that many buried targets would exist within the survey area, but that the density of buried clutter would not be so high as to preclude analysis of most buried targets as single items.[18] This was particularly important in the Data Fusion Demonstration as analysis algorithms were being evaluated that were intended to recover target shape information. The areas chosen for survey were also established such that they could be extended seamlessly into the woods to include both open and wooded areas.

3.4.1 Seeded Targets UXO benchmark items were seeded into the Demonstration area to provide additional ground truth that could be used to evaluate the relative performance of the MMS and EMMS using each navigation system. The dimensions of the survey area were expanded somewhat over those shown in Figure 4 (in red) to allow easier placement of the seed targets in relatively clear areas. Figure 5 shows a portion of the vehicular *MTADS* magnetometer survey with the new site perimeter defined in white. This image provides an impression of the densities of buried ferrous targets on the Range. The man-portable survey area extends an additional 35 meters from the shown southern perimeter into the woods.

The inert items, detailed in Table 3, range in size from M-23 (three pound practice bombs) to 105-mm projectiles. The vehicular surveys were used to choose burial sites near the woods that were relatively clear of other buried objects. Inert UXO seed targets buried in the woods were sited using hand-held metal detectors to define relatively clear burial sites. Backhoes and shovels were used to excavate, as required, for the seeded items. A commercial GPS surveyor was hired to locate the buried items as they were placed in the ground. GPS location was used in open areas. Items buried in the woods were located by laser survey equipment operating from GPS benchmarks. Orientations, and depths to the ordnance centers were recorded prior

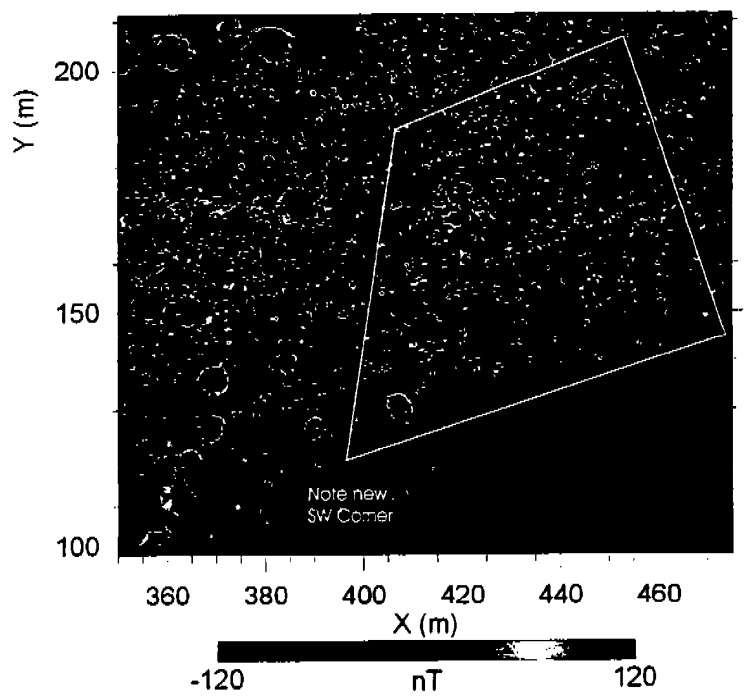

Figure 5. Magnetic anomaly map from an *MTADS* vehicular survey. The part of the man-portable survey area on the Range is bounded in white. The survey area extends an additional 35 meters into the woods.

to careful backfilling and tamping of the soil to minimize subsidence. At the same time the seed items were buried, a bush hog attached to the backhoe was used to partially clear brambles and underbrush from the wooded survey site. No trees or large saplings were removed and some areas were left with brush cover that would be difficult to walk through with the MMS and EMMS. It was expected that probably 10-15% of the wooded site would not be accessible to the man-portable instruments.

3.4.2 Preliminary Surveys Before beginning the man-portable surveys, the vehicular *MTADS* was used to again survey the area outlined in yellow in Figure 4 using both the magnetometer and EM arrays. The survey was extended as close as possible to the woods while maintaining acceptable GPS navigation fix quality. These data were used both for this Demonstration and for the ESTCP Data Fusion Demonstration. [18]

3.4.3 Establishing Survey Lanes The corners of the survey areas were established by the GPS surveyor and marked by bicycle flags. Wooden stakes were driven at 1-meter intervals along the east and west boundaries of the survey area. Twine was used to connect the east and west stakes defining the survey lanes. In the woods additional stakes were used within the site to maintain lane spacings as the twine snaked around trees and through the brush.

Table 2. Live ordnance recovered in the HFA Clearance

Number Recovered	UXO Item	Number Recovered	UXO Item
4	20-mm Rounds	3	2.36-in Rocket Motors
76	30-mm Rounds	2	2.75-in Rocket Warheads
21	CAD (explosive)	21	3.5-in Rocket
57	40-mm Rifle Grenades	1	5-in Rocket Warhead
1	M31 Rifle Grenades	1	2.75-in Rocket Motor
27	60-mm Mortars	71	Bomb Fuzes
116	81-mm Mortars	2	3.5-in Rocket Fuzes
36	4.2-in Mortars	3	81-mm Mortar Fuze
4	37-mm Projectiles	5	Fuze W/booster
4	75-mm Projectiles	4	Nose Fuzes
2	90-mm Projectiles	3	PD Fuze
3	105-mm Projectiles	2	M31 Warhead
2	106-mm Projectiles	4	Blu-7
1	57-mm Soviet Rocket Warhead	6	Blu-26

Table 3. Identification and locations of the inert UXO seed targets.

Target No	UXO ID	Location Latitude	Longitude	Location (UTM) Northing	Easting	Depth (m)	Azi. (deg)	Incl. (deg)
T-1	81-mm	38.408114616	-77.103106356	4253192.0	316371.4	0.21	45	45
T-2	M-23	38.408182890	-77.103135897	4253199.7	316369.0	0.15	0	0
T-3	4.2-in	38.408279866	-77102816841	4253209.8	316.397.1	0.63	45	45
T-4	105-mm	38.408362672	-77102673710	4253218.7	316409.8	0.69	45	45
T-5	2.75-in	38.408226790	-77.102714295	4253203.7	316405.9	0.30	90	0
T-6	M-23	38.408258385	-77.102623238	4253207.0	316413.9	0.18	45	0
T-7	81-mm	38.408306797	-77.102575035	4253212.3	316418.2	0.43		90
T-8	81-mm	38.408288164	-77.102524670	4253210.1	316422.6	0.28	0	0
T-9	2.75-in	38.408321734	-77.102495520	4253213.8	316425.2	0.28	0	45
T-10	81-mm	38.408324947	-77.102430749	4253214.0	316430.9	0.51	45	0
T-11	M-23	38.408367373	-77.102281185	4253218.4	316444.0	0.20		90
T-12	M-23	38.408374777	-77.102240512	4253219.2	316447.6	0.15	45	45
T-13	2.75-in	38.407993265	-77.102011424	4253176.4	316466.7	0.30	0	90
T-14	2.75-in	38.408122587	-77.102093780	4253190.9	316459.8	0.30	90	
T-15	M-23	38.408107204	-77.102238338	4253189.5	316447.1	0.15	0	0
T-16	M-23	38.40993279	-77.102292141	4253176.9	316442.2	0.15	45	0
T-17	60-mm	38.407977164	-77.102425350	4253175.4	316430.5	0.30	0	45
T-18	81-mm	38.407903350	-77.102445624	4253167..3	316428.5	0.48	45	45

4.0 L-Range Demonstration Approach

4.1 Performance Objectives

The performance objectives for this demonstration are very straight forward:[16]

- Conduct MMS and EMMS surveys of the entire survey area using the acoustic navigation system;
- Conduct MMS and EMMS surveys of the accessible areas using the GPS navigation system;
- Serially conduct *MTADS* target analyses for all man-portable surveys and the vehicular surveys. The vehicular EM survey data was analyzed using the 3-β classifier. Develop dig lists based upon each analysis and prepare dig images to reacquire and flag all targets picked from each survey;
- Dig all targets using UXO-qualified technicians. Document location, orientation, and identification of all recovered targets and photograph all UXO in-place before removal; and
- Analyze results to determine the relative performance achieved using each survey approach.

4.2 Physical Setup and Operation

The survey and data file log are summarized in Table 4. The open area was surveyed on 7/28/99 using the vehicular magnetometer array. On 8/03 the area was surveyed using the vehicular EM system, first in an east/west direction and then in a north/south direction. Two orthogonal EM surveys are typically used when conducting an EM 3-β analysis. Survey time periods were selected to allow vehicular surveying with good GPS coverage while working adjacent to the woods.

MMS and EMMS surveys were conducted using 0.25-meter lane spacings. During surveys using the GPS navigation system, survey times were chosen to allow good GPS coverage while working adjacent to the woods. Figures 1 and 2 show MMS and EMMS surveys underway in the 5000 m^2 open range area. As shown in Figure 2, EMMS surveys using the GPS navigation system were conducted as two-man operations because the weight of equipment was too high to comfortably carry in a single backpack. All other man-portable surveys required only a single operator and a single backpack. Reduction of weight and consolidation of all equipment into a single backpack was addressed in the system upgrade in preparation for the JPG demonstration. A single acoustic navigation beacon setup was used to conduct the MMS and EMMS surveys in the open area. The survey bounds are as shown in Figure 5. A second beacon setup was used to conduct the 3300 m^2 surveys within the woods. Man-portable surveys of the open area required 3-3.5 hours with either system. Surveys of the wooded area required about 3 hours each, including set up of the acoustic navigation system.

Table 4. Survey log for the vehicular and man-portable surveys.

Platform	Navigation	Survey Area	Files	Date	Survey Time
Vehicle/Mags	GPS	Fusion/MP Open Area	99209499 99209544 99209614	7/28/99	126 minutes
Vehicle/EM (East/West)	GPS	Fusion/MP Open Area	99215497 99215577 99215624 99215644 99215545	8/03/99	294 minutes
Vehicle/EM (North/South)	GPS	Fusion/MP Open Area	99215721 99216524 99216555 99216595 99216628 99216699	8/03-04/99	267 minutes
MMS	GPS	MP Open Area	99217002 99217003 99218003	8/05-06/99	208 minutes
EMMS	GPS	MP Open Area	99218004 99218005 99218006 99218007	8/06/99	196 minutes
EMMS	Acoustic	MP Open Area MP Open Area MP Open Area MP Open Area MP Open Area MP Woods MP Woods MP Woods	00221001 99221002 99221003 99222001 99222002 99222003 99223003 99223004	8/09-11/99	216 minutes 145 minutes
MMS	Acoustic	MP Open Area MP Open Area MP Woods MP Woods MP Woods	99224001 99224002 99222005 99222006 99223001	8/12/99 8/10-11/99	170 minutes 165 minutes

An example man-portable survey is shown in Figure 6. The areas north and east of the yellow lines were also included in the ESTCP Data Fusion Demonstration Survey. Only vehicular data were used in that demonstration, however. Area within the white perimeter line constitutes the man-portable survey area. Area south of the red line was effectively within the woods and could not be surveyed using the GPS navigation system. The largest missed survey area in the woods (at about X=110, Y=10) was excluded because it contained the decaying corpse of a large deer who expired after the seed targets were placed, but before the surveys took place. As there were no seed

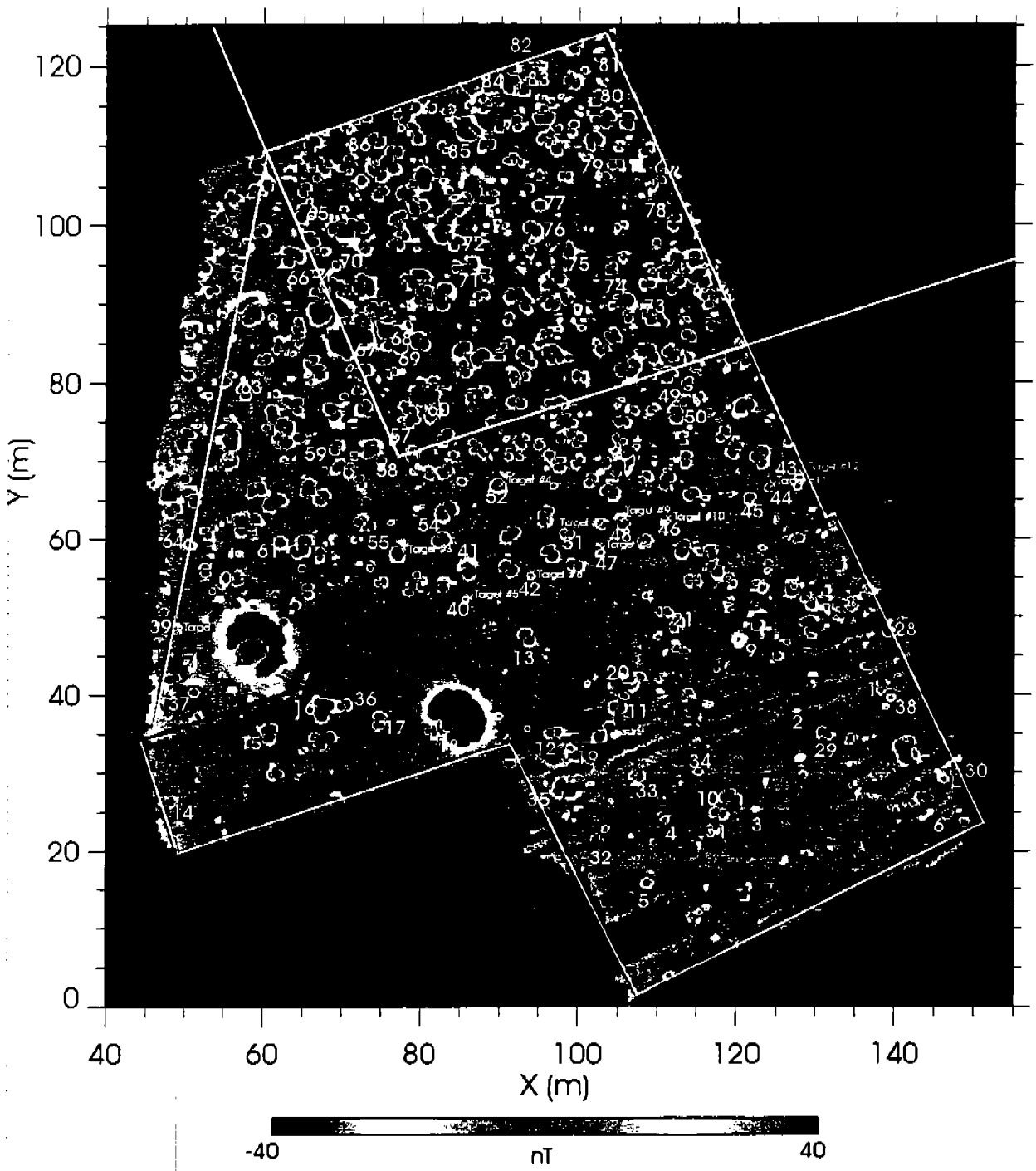

Figure 6. Magnetic anomaly image of the man-portable survey area taken using the acoustic navigation system.

targets within this area, it was not surveyed. Other apparent missed areas included groups of trees or brush areas that could not be navigated with the magnetometer cart. Some of the seeded targets are identified in the image and labeled with their target numbers.

Figure 7 shows two of the EM surveys. The east-west vehicular survey is shown on the left. On the right, the composite images from the man-portable surveys using the acoustic navigation system are shown. Two impressions are immediately apparent. The man-portable EM survey equipment is much less sensitive than the vehicular array. Note the sensitivity levels on the plots. The 0.5 X 1.0 meter coil produces peak signals 12-16 times less intense than from the vehicular array, depending upon target size and depth. The peak signal strength from the 1.0 X 1.0 m man-portable EM coils is about 4 times less intense than from the vehicular array. The sensitivity of the half and one meter coils scale directly with the area of the transmit and receive coils. Only the 0.5 X 1.0 meter man-portable coils were used in this demonstration. The results of this decreased sensitivity will become apparent when the performance of the system is analyzed.

The second visual impression left by the man portable image in Figure 7 is that the EMMS survey coverage in the woods was poor compared to the coverage of the MMS survey. This is a result of poor quality control in the survey process. Either a complete survey was not taken, or survey files were lost, leaving gaps in the coverage. The extent of the missed areas was not realized until it was too late to recover and resurvey these areas. In retrospect, the wooded areas should have been gridded twice and surveyed in orthogonal directions to improve coverage. In a real world operation, to assure complete coverage and detection of all UXO, hand surveys using fluxgate gradiometers or metal detectors would be required to survey in brushy areas and in missed areas adjacent to trees. All survey images from the L-Range are shown in Appendices on the included CD-ROM. In addition, dig images which were prepared for reacquisition of the targets for digging are presented in Appendix C.

4.3 Sampling and Analysis Procedures

Parts of the man-portable survey area were covered by 7 separate surveys; 2 vehicular EM surveys, 1 vehicular magnetometer survey, 2 MMS surveys (GPS and acoustic navigation) and 2 EMMS surveys (GPS and acoustic navigation). The area in the woods was surveyed only by the MMS and EMMS using the acoustic navigation system.

The area in the Data Fusion Demonstration (north and east of the yellow lines in Figures 6 and 7) was analyzed using the 3-β classifier and the point dipole magnetometer target fitting algorithm. 201fusion targets were chosen for analysis and digging. These included 6 of the Man-Portable Seed Targets and 24 additional targets within the man-portable survey area. These 24 targets were therefore accepted as targets in the man-portable analyses. No attempt was made in the Data Fusion Demonstration to be inclusive in the target selection and analysis. Indeed, only 10-15% of the buried objects large enough to be UXO items were chosen for analysis and digging.

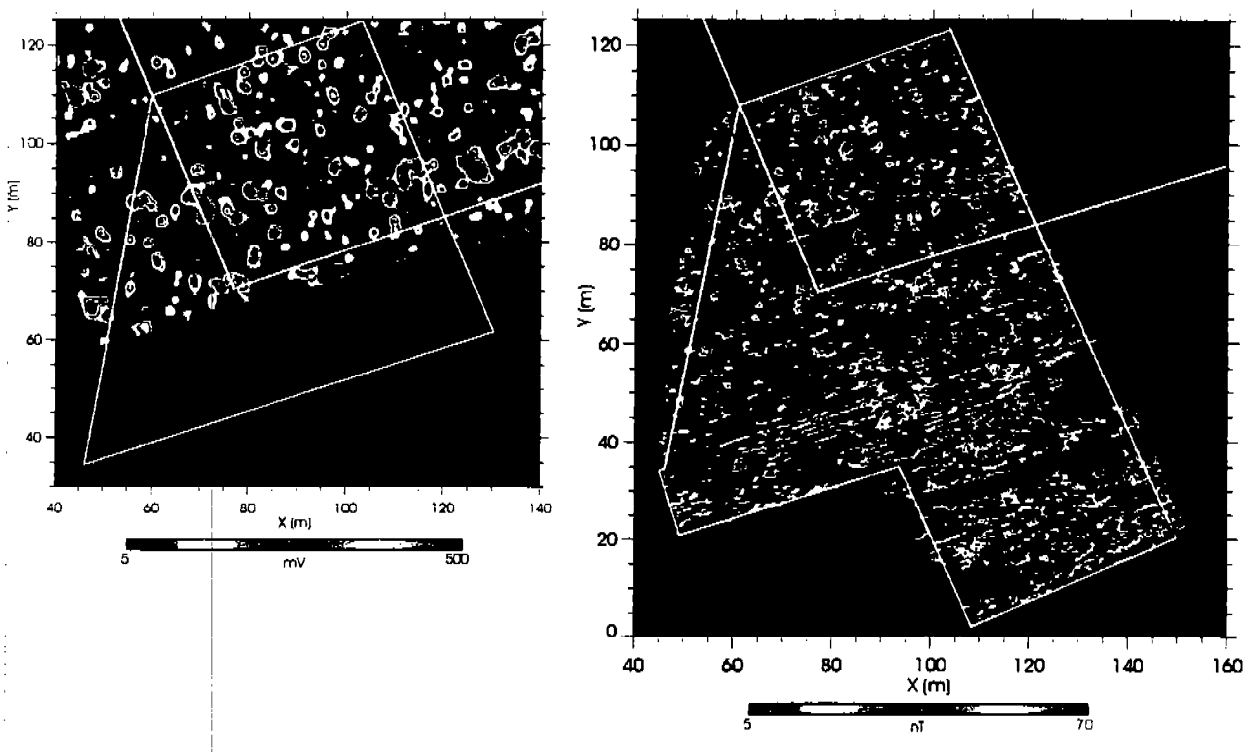

Figure 7. EM anomaly images of the man-portable survey area. On the left the vehicular survey using GPS navigation is presented. The right image shows the EM man-portable survey using the acoustic navigation system. Note the change in signal scale factors between the plots.

In the man-portable demonstration, the data from the various surveys were serially analyzed. A complete analysis of the man-portable MMS survey using the acoustic navigation system was initially carried out. The coordinates of the 24 3-β fusion targets were flagged to be certain that they were included in this and all subsequent analyses. A total of 91 targets were chosen for the dig list in the man-portable survey area. This included the 18 seed targets and the 24 3-β Fusion targets in the MMS (acoustic nav) survey.

The acoustic MMS target analysis was then carried through the remainder of the survey data sets, analyzing the same targets in each data set when the targets were visible. Some targets were not analyzed in some data sets because they fell within missed survey areas, or because the targets were not detectible or analyzable. Only the east/west vehicular *MTADS* EM data were analyzed. They were analyzed using the point dipole baseline algorithm to provide a comparison with the 3-β analysis. Figure 8 shows a portion of a magnetic anomaly image from the vehicular *MTADS* magnetometer survey. Only a fraction of the total visible targets were chosen for digging. The number of targets dug was resource limited. All targets were chosen from the Fusion Dig List and were supplemented with targets on the range that, on analysis, appeared to be likely UXO objects. Within the woods, a significant fraction of the total targets were specified for digging because the target density was much lower than on the range. Many of these targets were improbable as UXO because they had complex signatures or significant remnant moments. Target numbers in Figure 8 were from the Fusion Target Dig List, except when the target number is preceded by an "M." The M-designated targets were not considered in the 3-β Fusion Demonstration.

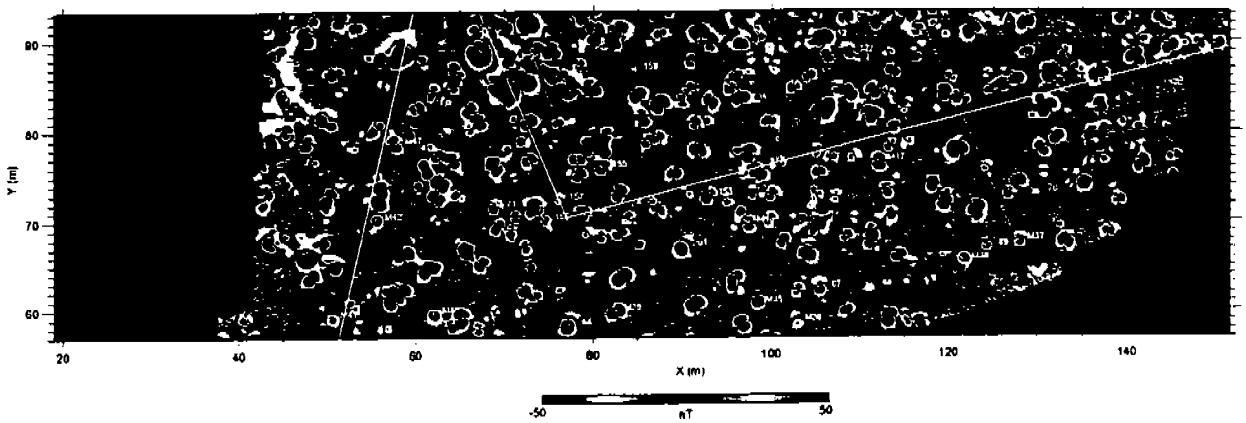

Figure 8. Composite magnetic anomaly image from the man-portable survey area. A larger copy of this image is used by the target reacquisition team and by the dig team to guide their operations.

5.0 L-Range Performance Assessment

5.1 Performance Data

In Table 5 the analyses for the 18 Seed Targets are documented. The Ground Truth entry lists the UTM coordinates measured when the UXO target was buried, and its measured depth and orientation. Each UXO item has analysis entries for all surveys in which it was detected and fit. The Fusion Analysis Demonstration covered only 6 of the Seed Targets. Targets 13-18, located in the woods, were surveyed only by the MMS and EMMS (acoustic nav) surveys.

In Table 6 the same information is provided for the 39 targets located on the Range in areas that were surveyed using at least one of the GPS-navigated surveys. Not all GPS surveys covered exactly the same areas because satellite positions are more favorable at some times than others allowing closer approach to the tree line. The listed "Ground Truth" information includes only the UXO supervisor's description of the item, its approximate depth and some orientation information. Position information relative to the flag is not included because the information provided by the dig teams was not precise or comprehensive, and the flags were positioned in some cases based upon the vehicular magnetometer survey Fusion analysis and in other cases upon the analysis of the MMS (acoustic survey) analysis.

In Table 7 the MMS and EMMS survey results are provided for the 31 targets that were on the dig list from the surveys in the woods. The 6 Seed Targets in the woods were included in Table 5. A total of 90 targets were flagged and dug by the UXO-certified remediation team. A dig sheet was filled out for each target recording the identification of the item, its location relative to the flag, and its depth and orientation. All UXO items were photographed before removal from the hole. A summary of the recovered items is included in Table 8.

Table 5. Survey Analyses for the Seed Targets.

Target ID	Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
SEED T1	Ground Truth		316371.36	4253192.02			0.53		0.081	45	45		81mm Mortar, 60 deg nose down, Pointing NE, 1.5 ft deep
81-mm mortar	Vehicle Mag EW	1	316371.24	4253191.90	51.48	40.58	0.51		0.083	40	15	0.962	
	Vehicle EM EW	1	316371.21	4253191.62	51.45	40.30	0.01	0.05	0.083				
	Fusion Fit	FUS-63	316371.21	4253191.89	51.45	40.57	0.45	0.38	0.077	44	10	0.980	
	MP Mag GPS	1	316371.27	4253191.89	51.51	40.57	0.52		0.086	47	17	0.948	
	MP Mag ACO	37	316371.07	4253191.83	51.31	40.51	0.62		0.088	43	12	0.949	
	MP EM GPS	1	316371.20	4253191.91	51.44	40.59	0.03	0.03	0.036				
	MP EM ACO	44	316371.54	4253191.58	51.78	40.26		0.00	0.018			0.545	
SEED T2	Ground Truth		316368.95	4253199.66			0.15			0	0		M23 pointing N, Flag 2.7 in N
M-23	Vehicle Mag EW	2	316369.20	4253199.63	49.43	48.31	0.17	0.05		25	334	0.87	
	Vehicle EM EW	2	316369.12	4253199.98	49.36	48.66	0.50	0.08	0.182				
	Fusion Fit												
	MP Mag GPS	2	316369.08	4253199.64	49.31	48.32	0.13		0.051	29	348	0.866	
	MP Mag ACO	39	316368.84	4253199.50	49.07	48.18	0.12		0.044	27	353	0.873	
	MP EM GPS	2	316369.24	4253199.58	49.48	48.26	0.27	0.06	0.099				
	MP EM ACO	43	316368.98	4253199.63	49.21	48.31		0.25	0.050			0.747	
SEED T3	Ground Truth		316397.06	4253209.79			0.64		0.107	45	45		4.2 in Stokes Mortar, 2.5 ft deep
4.2-in Mortar	Vehicle Mag EW	8	316397.17	4253209.84	77.40	58.52	0.76	0.12		56	50	0.945	
	Vehicle EM EW	4	316396.81	4253209.95	77.04	58.63	0.56	0.11	0.277				
	Fusion Fit	FUS-64	316397.13	4253209.74	77.37	58.42	0.79	0.51	0.118	68	63	0.947	
	MP Mag GPS	5	316397.11	4253209.74	77.34	58.42	0.68		0.112	56	41	0.956	
	MP Mag ACO	55	316396.92	4253209.52	77.15	58.20	0.81		0.115	55	39	0.970	
	MP EM GPS	5	316397.18	4253209.85	77.42	58.53	0.00	0.03	0.036				
	MP EM ACO	34	316396.65	4253209.56	76.88	58.24		0.82	0.097			0.579	
SEED T4	Ground Truth		316409.77	4253218.69			0.69		0.105	45	45		105 mm Proj. @ 2.0 ft.
105-mm Proj	Vehicle Mag EW	22	316409.85	4253218.68	90.09	67.36	0.78	0.11		48	40	0.967	
	Vehicle EM EW	10	316409.81	4253218.70	90.05	67.38	0.31	0.07	0.140				
	Fusion Fit	FUS-201	316409.84	4253218.62	90.08	67.30	0.82	0.56	0.115	58	49	0.979	
	MP Mag GPS	9	316409.80	4253218.72	90.04	67.40	0.68		0.106	49	46	0.951	
	MP Mag ACO	52	316409.72	4253218.25	89.96	66.93	0.79		0.111	55	38	0.964	
	MP EM GPS	11	316409.11	4253219.14	89.35	67.82	0.00	0.02	0.013				
	MP EM ACO	31	316410.17	4253218.65	90.41	67.33		0.09	0.033			0.389	
SEED T5	Ground Truth		316405.88	4253203.69			0.18		0.070	0	90		2.75 in WH, @ 1 ft.
2.75-in WH	Vehicle Mag EW	6	316405.96	4253203.77	86.20	52.45	0.30	0.05	-	59	29	0.962	
	Vehicle EM EW	5	316405.82	4253203.61	86.05	52.29		0.46	0.082			0.867	
	Fusion Fit	FUS-66	316405.96	4253203.73	86.19	52.41	0.30	0.26	0.047	70	37	0.980	
	MP Mag GPS	3	316405.86	4253203.82	86.10	52.50	0.26	0.05	0.067	70	25	1	
	MP Mag ACO	40	316405.57	4253203.42	85.81	52.10	0.29		0.044	62	48	0.971	
	MP EM GPS	7	316405.47	4253203.63	85.71	52.31		0.32	0.044			0.419	
	MP EM ACO	46	316405.88	4253203.17	86.11	51.85		0.21	0.046			0.579	

Table 5. Survey Analyses for the Seed Targets, Continued

Target ID	Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
SEED T6	Ground Truth		316413.91	4253207.02			0.18			0	45		60 mm Mortar, 30 deg nose down, 0.5 ft deep, under flag
M-23	Vehicle Mag EW	11	316413.98	4253206.99	94.22	55.67	0.24	0.06		42	325	0.946	
	Vehicle EM EW	9	316414.12	4253206.78	94.36	55.47		0.00	0.048			0.874	
	Vehicle EM EW	8	316414.08	4253206.82	94.32	55.50		0.01	0.052			0.836	
	Fusion Fit												
	MP Mag GPS	34	316413.94	4253206.98	94.17	55.66	0.23		0.054	46	345	0.912	
	MP Mag ACO	42	316413.62	4253206.58	93.85	55.26	0.20		0.047	42	339	0.921	
	MP EM GPS	9	316414.10	4253206.66	94.34	55.34	0.01	0.04	0.045				
	MP EM ACO	32	316414.79	4253206.43	95.03	55.11		0.00	0.035			0.543	
SEED T7	Ground Truth		316418.24	4253212.29			0.43		0.081	90	0		81 mm mortar, 0.75 ft deep, nose down to W, under flag
81 mm Mortar	Vehicle Mag EW	12	316418.19	4253212.26	98.43	60.94	0.53	0.10		76	290	0.941	
	Vehicle EM EW	11	316418.22	4253212.27	98.46	60.95		0.00	0.051			0.929	
	Fusion Fit												
	MP Mag GPS	35	316418.13	4253212.18	98.37	60.86	0.49		0.104	81	211	0.889	
	MP Mag ACO	51	316418.30	4253211.97	98.54	60.65	0.60		0.101	74	10	0.900	
	MP EM GPS	10	316418.30	4253212.17	98.54	60.85	0.00	0.04	0.052				
	MP EM ACO	28	316418.19	4253211.96	98.43	60.64		0.00	0.031			0.739	
SEED T8	Ground Truth		316422.59	4253210.13			0.43		0.081	0	0		81mm Mortar, nose down, 1.5 ft deep
81 mm Mortar	Vehicle Mag EW	13	316422.59	4253210.16	102.83	58.84	0.48	0.07		27	342	0.96	
	Vehicle EM EW	12	316422.70	4253209.94	102.94	58.62	0.72	0.12	0.334				
	Fusion Fit												
	MP Mag GPS	36	316422.58	4253210.04	102.82	58.72	0.43		0.070	22	350	0.901	
	MP Mag ACO	51	316418.30	4253211.97	98.54	60.65	0.60		0.101	74	10	0.915	
	MP EM GPS	12	316422.86	4253209.88	103.09	58.56	0.02	0.03	0.033				
	MP EM ACO	27	316422.51	4253209.96	102.75	58.64		0.00	0.018			0.397	
SEED T9	Ground Truth		316425.22	4253213.79			0.28		0.070	45	0		2.75 in WH, 1.0 ft deep, 45 deg
2.75 in WH	Vehicle Mag EW	14	316425.14	4253213.76	105.38	62.44	0.29	0.08		55	346	0.977	
	Vehicle EM EW	13	316425.32	4253213.57	105.55	62.25	0.00	0.05	0.080				
	Fusion Fit												
	MP Mag GPS	6	316425.19	4253213.71	105.43	62.39	0.28		0.084	50	349	0.921	
	MP Mag ACO	47	316422.31	4253209.59	102.54	58.27	0.47		0.066	32	343	0.961	
	MP Mag ACO	48	316425.31	4253213.31	105.55	61.99	0.32		0.086	66	349	0.961	
	MP EM GPS	13	316425.36	4253213.52	105.60	62.20	0.13	0.05	0.073				
	MP EM ACO	26	316425.30	4253213.10	105.53	61.78		0.00	0.034			0.515	
SEED T10	Ground Truth		316430.89	4253214.02			0.51		0.081	0	45		81mm Mortar @ 2.0 ft, pointing NE
81 mm Mortar	Vehicle Mag EW	15	316430.93	4253213.92	111.16	62.60	0.54	0.06		47	39	0.897	
	Vehicle EM EW	14	316430.92	4253213.95	111.15	62.63	0.98	0.12	0.322				
	Fusion Fit	FUS-68	316430.90	4253213.93	111.13	62.61	0.62	0.53	0.066	53	35	0.941	
	MP Mag GPS	7	316430.84	4253213.83	111.08	62.51	0.69		0.064	79	136	0.741	
	MP Mag ACO	46	316430.64	4253213.43	110.87	62.11	0.51		0.057	40	25	0.933	
	MP EM GPS	14	316430.61	4253213.87	110.84	62.55	0.21	0.04	0.058				
	MP EM ACO	25	316430.90	4253212.73	111.14	61.41		0.00	0.016			0.326	

Table 5. Survey Analyses for the Seed Targets, Continued

Target ID	Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
SEED T11	Ground Truth		316444.05	4253218.43			0.20			90	0		M 23 @0.5 ft,
M 23	Vehicle Mag EW	17	316443.97	4253218.43	124.21	67.11	0.17	0.06		82	144	0.979	
	Vehicle EM EW	16	316444.05	4253218.45	124.29	67.13	0.00	0.05	0.073				
	Fusion Fit	FUS-69	316443.97	4253218.43	124.20	67.11	0.18	0.16	0.063	84	147	0.983	
	MP Mag GPS	8	316444.15	4253218.51	124.38	67.19	0.13		0.063	90	270	0.978	
	MP Mag ACO	44	316443.85	4253217.59	124.09	66.28	0.20		0.057	77	135	0.797	
	MP EM GPS	16	316443.95	4253218.47	124.19	67.15	0.00	0.04	0.044				
	MP EM ACO	23	316443.44	4253217.63	123.68	66.31		0.00	0.038			0.762	
SEED T12	Ground Truth		316447.62	4253219.17			0.15			45	45		Mk23, 3 in deep, under flag
M 23	Vehicle Mag EW	18	316447.66	4253219.25	127.89	67.93	0.10	0.06		26	10	0.904	
	Vehicle EM EW	17	316447.70	4253218.80	127.93	67.48	0.00	0.03	0.034				
	Fusion Fit												
	MP Mag GPS	37	316447.58	4253219.08	127.82	67.76	0.07		0.050	58	37	0.898	
	MP Mag ACO	43	316447.49	4253218.23	127.73	66.91	0.16		0.057	23	22	0.913	
	MP EM GPS	17	316447.74	4253219.01	127.97	67.69	0.00	0.04	0.045				
	MP EM ACO	22	316447.65	4253218.59	128.09	67.27		0.00	0.022			0.662	
SEED T13	Ground Truth		316466.66	4253176.38			0.30		0.070	90	0		2.75 in WH, nose down, 12 in to tail, Flag 2 in N, 26 in E
2.75 in WH	MP Mag ACO	6	316466.34	4253176.03	146.57	24.71	0.46		0.096	90	275	0.717	
	MP EM ACO	61	316467.15	4253176.53	147.39	25.21		0.00	0.024			0.674	
SEED T14	Ground Truth		316459.80	4253190.89			0.30		0.070	0	90		
2.75 in WH													
	MP Mag ACO	38	316459.43	4253191.01	139.66	39.69	0.43		0.055	34	19	0.732	
	MP EM ACO												
SEED T15	Ground Truth		316447.14	4253189.47			0.15			0	0		Mk23, 7 in deep, Flag 18 in N, 12 in
M 23	MP Mag ACO	2	316447.34	4253189.83	127.57	38.51	0.68		0.074	59	20	0.875	
	MP EM ACO	60	316446.98	4253189.77	127.22	38.45		0.00	0.023			0.552	
SEED T16	Ground Truth		316442.15	4253176.94			0.15			0	45		Mk23, , nose down, 11 in deep,
M 23	MP Mag ACO	3	316442.26	4253176.80	122.50	25.48	0.37		0.049	39	20	0.882	
	MP EM ACO		316443.34	4253176.90	123.58	25.58		0.00	0.020			0.700	
SEED T17	Ground Truth		316430.48	4253175.41			0.30		0.060	45	0		60mm Mortar, 45 deg nose down, 6 in to tail, Flag 13 in N
60 mm Mortar	MP Mag ACO	4	316430.60	4253175.47	110.84	24.15	0.34		0.052	40	317	0.896	
	MP EM ACO	56	316430.18	4253174.27	110.42	22.95		0.00	0.028			0.251	
SEED T18	Ground Truth		316428.52	4253167.26			0.48		0.081	45	45		81mm Mortar, 45 deg nose down, 14 in to tail, Flag 30 in N, 20 in E
81mm Mortar	MP Mag ACO	5	316428.64	4253167.30	108.88	15.98	0.67		0.084	51	25	0.910	
	MP EM ACO	55	316428.83	4253167.67	109.07	16.35		0.00	0.017			0.305	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													25lb Frag Bomb @12 in.nose down 45 deg
Vehicle Mag EW	7	316406.09	4253207.32	86.32	56.00	0.31	0.10		0.5535	67	323	0.932	
Vehicle EM EW	6	316406.20	4253207.13	86.44	55.81		0.00	0.058				0.949	
Fusion Fit	FUS-65	316406.09	4253207.32	86.33	56.00	0.31	0.29	0.101	0.5590	68	324	0.932	
MP Mag GPS	4	316406.01	4253207.35	86.24	56.03	0.26		0.098	0.5033	52	342	0.878	
MP Mag ACO	41	316405.93	4253207.09	86.17	55.77	0.36		0.103	0.6018	65	358	0.883	
MP EM GPS	8	316406.33	4253207.19	86.57	55.87		0.06	0.062				0.892	
MP EM ACO	45	316406.21	4253206.95	86.45	55.63		0.30	0.057				0.860	
Ground Truth													81 mm Mortar, unfuzed
Vehicle Mag EW	26	316394.27	4253221.68	74.51	70.36	0.20	0.06		0.1336	47	301	0.941	
Vehicle EM EW	3	316394.32	4253221.68	74.56	70.36		0.42	0.106				0.804	
Fusion Fit	FUS-156	316394.30	4253221.68	74.53	70.36	0.21	0.23	0.062	0.1320	51	309	0.953	
MP Mag GPS	10	316394.32	4253221.23	74.56	69.91	0.14		0.063	0.1379	80	202	0.836	
MP Mag ACO	58	316394.59	4253221.22	74.82	69.90	0.21		0.057	0.0999	49	323	0.931	
MP EM GPS	23	316394.25	4253221.59	74.49	70.27		0.23	0.066				0.591	
MP EM ACO	38	316394.14	4253221.02	74.38	69.71		0.02	0.045				0.748	
Ground Truth													81 mm Mortar, illumination,dirt filled, near surface
Vehicle Mag EW	23	316398.53	4253222.35	78.77	71.03	0.09	0.07		0.2058	26	1	0.894	
Vehicle EM EW	5	316398.70	4253222.46	78.94	71.14		0.08	0.092				0.92	
Fusion Fit	FUS-154	316398.54	4253222.35	78.77	71.03	0.10	0.01	0.074	0.2240	26	2	0.907	
MP Mag GPS	11	316398.79	4253222.19	79.02	70.87	0.11		0.063	0.1351	78	125	0.96	
MP Mag ACO	56	316398.57	4253221.92	78.81	70.60	0.16		0.069	0.1786	43	3	0.918	
MP EM GPS	19	316399.39	4253222.75	79.63	71.43		0.00	0.031				0.176	
MP EM ACO	36	316399.07	4253222.03	79.31	70.71		0.07	0.062				0.648	
Ground Truth													81mm Mortar, 3 in deep, 6 in S of Flag
Vehicle Mag EW	27	316388.62	4253223.02	68.86	71.70	0.14	0.07		0.1552	40	30	0.944	
Vehicle EM EW	2	316388.67	4253222.97	68.90	71.65		0.00	0.061				0.922	
Fusion Fit	FUS-71	316388.62	4253223.02	68.85	71.70	0.14	0.10	0.066	0.1550	40	29	0.944	
MP Mag GPS	12	316388.50	4253222.96	68.74	71.64	0.19		0.069	0.1814	49	41	0.715	
MP Mag ACO	59	316388.99	4253222.64	69.22	71.32	0.18		0.066	0.1529	43	50	0.946	
MP EM GPS	24	316388.50	4253222.89	68.73	71.57		0.12	0.064				0.84	
MP EM ACO	39	316388.79	4253222.35	69.03	71.03		0.11	0.059				0.919	
Ground Truth													81mm Mortar, split in half, 0.25 ft deep
Vehicle Mag EW	25	316395.94	4253223.81	76.18	72.49	0.10	0.05		0.0517	31	25	0.97	
Vehicle EM EW	4	316395.85	4253223.81	76.08	72.49		0.00	0.035				0.761	
Fusion Fit	FUS-157	316395.95	4253223.81	76.18	72.49	0.09	0.12	0.045	0.0490	32	27	0.977	
MP Mag GPS	13	316396.00	4253223.86	76.23	72.56	0.04		0.035	0.0235	47	21	0.681	
MP Mag ACO	57	316396.24	4253223.61	76.48	72.29	0.10		0.040	0.0358	28	19	0.895	
MP EM GPS	22	316395.81	4253223.78	76.05	72.46		0.25	0.062				0.632	
MP EM ACO	37	316396.12	4253223.37	76.36	72.05		0.14	0.056				0.766	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													81 mm Mortar at 0.75 ft, scrap above on surface
Vehicle Mag EW	21	316412.64	4253224.25	92.88	72.93	0.24	0.08		0.2837	24	65	0.833	
Vehicle EM EW	10	316412.57	4253224.01	92.81	72.69		0.27	0.076				0.833	
Fusion Fit	FUS-153	316412.64	4253224.25	92.88	72.93	0.22	0.29	0.078	0.2570	24	69	0.829	
MP Mag GPS	14	316412.50	4253224.10	92.74	72.78	0.12		0.070	0.1870	15	53	0.842	
MP Mag ACO	53	316412.57	4253223.75	92.80	72.43	0.23		0.076	0.2402	22	57	0.878	
MP EM GPS	21	316412.20	4253224.04	92.44	72.72		0.48	0.072				0.847	
MP EM ACO	30	316413.07	4253223.51	93.31	72.19		0.11	0.045				0.689	
Ground Truth													81 mm Mortar at 0.5 ft, nose down
Vehicle Mag EW	24	316400.79	4253227.50	81.02	76.18	0.18	0.08		0.3147	59	44	0.942	
Vehicle EM EW	9	316400.78	4253227.55	81.01	76.23		0.21	0.088				0.572	
Fusion Fit	FUS-155	316400.79	4253227.38	81.02	76.06	0.19	0.19	0.083	0.3150	63	116	0.943	
MP Mag GPS	15	316401.04	4253227.52	81.27	76.20	0.20		0.090	0.3982	57	76	0.842	
MP Mag ACO	60	316401.13	4253227.06	81.36	75.74	0.26		0.091	0.4157	58	47	0.958	
MP EM GPS	20	316401.00	4253227.65	81.24	76.33		0.03	0.053				0.824	
MP EM ACO	35	316401.02	4253226.79	81.26	75.47		0.00	0.048				0.909	
Ground Truth													2 ft long, 1/4 in wire at 0.5 ft.
Vehicle Mag EW	19	316433.02	4253229.62	113.26	78.30	0.17	0.06		0.1164	25	41	0.864	
Vehicle EM EW	11	316433.65	4253229.80	113.89	78.48		0.00	0.025				0.564	
Fusion Fit	FUS-121	316433.03	4253229.63	113.27	78.31	0.17	0.27	0.061	0.1220	23	43	0.877	
MP Mag GPS	16	316432.78	4253229.59	113.02	78.27	0.16		0.062	0.1302	25	45	0.826	
MP Mag ACO	49	316432.97	4253228.76	113.21	77.44	0.25		0.062	0.1277	27	38	0.747	
MP EM GPS	18	316432.19	4253228.29	112.41	76.97		0.10	0.027				0.410	
MP EM ACO	21	316433.37	4253229.06	113.61	77.74		0.00	0.020				0.446	
Ground Truth													OE Frag, 2 in X 1 in X 1/8 in, 6 in deep, Under Flag
Vehicle Mag EW	20	316431.77	4253227.88	112.01	76.56	0.22	0.09		0.3346	15	9	0.937	
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	17	316431.87	4253227.93	112.11	76.61	0.16		0.087	0.3516	22	18	0.893	
MP Mag ACO	50	316431.99	4253226.95	112.22	75.63	0.19		0.086	0.3477	18	359	0.926	
MP EM GPS	18	316432.19	4253228.29	112.42	76.97		0.10	0.027				0.412	
MP EM ACO	20	316431.57	4253226.39	111.81	75.07		0.00	0.017				0.263	
Ground Truth													81mm Mortar at 0.25 ft, deep, 12 in E of flag
Vehicle Mag EW	28	316396.23	4253236.00	76.47	84.68	0.45	0.15		1.7020	10	270	0.66	
Vehicle EM EW	8	316397.41	4253236.02	77.65	84.70		0.21	0.102				0.934	
Fusion Fit	FUS-185	316397.18	4253236.04	77.42	84.72	0.45	0.20	0.121	0.9550	35	14	0.763	
MP Mag GPS	18	316396.38	4253236.08	76.62	84.76	0.30		0.119	0.9063	10	278	0.607	
MP Mag ACO	68	316396.32	4253236.02	76.55	84.70	0.42		0.129	1.1608	19	267	0.630	
MP EM GPS	25	316397.48	4253236.09	77.72	84.77		0.00	0.076				0.932	
MP EM ACO	13	316397.39	4253236.06	77.62	84.74		0.13	0.079				0.915	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													2 in angle iron, 4 ft long, at surface
Vehicle Mag EW	30	316390.56	4253236.64	70.80	85.32	0.00	0.12		0.9481	-39	91	0.395	
Vehicle EM EW	6	316390.77	4253236.90	71.00	85.58		0.45	0.216				0.764	
Fusion Fit	FUS-183	316390.88	4253236.94	71.12	85.62	0.37	0.36	0.270	10.7040	-6	33	0.846	
MP Mag GPS	19	316390.64	4253236.94	70.88	85.62	0.37		0.262	9.7758	-23	39	0.904	
MP Mag ACO	67	316390.85	4253236.93	71.08	85.61	0.35		0.247	8.1298	12	39	0.917	
MP EM GPS	27	316390.95	4253236.87	71.18	85.65		0.29					0.820	
MP EM ACO	12	316391.07	4253237.22	71.30	85.90		0.39	0.150				0.600	
Ground Truth													2 pieces of frag , 5 in deep, 10 in E & W of Flag
Vehicle Mag EW	29	316395.68	4253237.46	75.91	86.14	0.48	0.13		1.1613	54	117	0.851	
Vehicle EM EW	7	316395.18	4253237.89	75.41	86.57		0.58	0.101				0.876	
Fusion Fit	FUS-184	316395.68	4253237.49	75.91	86.17	0.40	0.68	0.115	0.8300	59	107	0.888	
MP Mag GPS	20	316395.38	4253237.48	75.62	86.16	0.34		0.117	0.8583	42	78	0.762	
MP Mag ACO	69	316395.73	4253237.47	75.96	86.15	0.55		0.135	1.3463	50	114	0.887	
MP EM GPS	27	316390.95	4253236.97	71.18	85.65		0.29	0.139				0.82	
MP EM GPS	26	316395.23	4253237.81	75.46	86.49		0.73	0.092				0.579	
MP EM ACO	10	316395.24	4253237.89	75.48	86.57		0.68	0.086				0.411	
Ground Truth													81 mm Mortar, nose down at 0.25 ft
Vehicle Mag EW	46	316428.48	4253240.07	108.72	88.75	0.19	0.07		0.1557	31	10	0.895	
Vehicle EM EW	12	316428.62	4253240.16	108.85	88.84		0.15	0.079				0.91	
Fusion Fit	FUS-122	316428.49	4253240.06	108.73	88.75	0.18	0.15	0.064	0.1420	34	15	0.894	
MP Mag GPS	21	316428.48	4253240.09	108.72	88.77	0.26		0.072	0.1991	45	342	0.778	
MP Mag ACO	73	316428.37	4253240.04	108.60	88.72	0.23		0.063	0.1365	33	19	0.927	
MP EM GPS	37	316428.70	4253240.27	108.94	88.95		0.00	0.042				0.634	
MP EM ACO	19	316428.82	4253239.38	109.05	88.06		0.24	0.070				0.800	
Ground Truth													Rocket, 5 in diam, 64 in long, at 3.26 ft, pointing E/W
Vehicle Mag EW	33	316386.59	4253242.34	66.83	91.02	0.17	0.07		0.1601	6	317	0.935	
Vehicle EM EW													
Fusion Fit	FUS-181	316387.22	4253240.25	67.45	88.93	1.17	1.17	0.180	3.1570	81	75	0.948	
MP Mag GPS	22	316386.36	4253241.72	66.59	90.40	0.27		0.068	0.1708	0	310	0.866	
MP Mag ACO	66	316386.57	4253242.43	66.80	91.11	0.22		0.064	0.1403	11	309	0.823	
MP EM GPS													
MP EM ACO	11	316387.03	4253243.05	67.27	91.73		0.00	0.019				0.633	
Ground Truth													2 pieces of OE Scrap, 4 & 2 in long @ 4 in deep
Vehicle Mag EW	45	316425.45	4253241.60	105.68	90.28	0.08	0.11		0.6931	2	66	0.975	
Vehicle EM EW	13	316424.88	4253241.62	105.12	90.30		0.00	0.048				0.934	
Fusion Fit	FUS-152	316425.45	4253241.60	105.68	90.28	0.08	0.05	0.108	0.6880	2	66	0.974	
MP Mag GPS	23	316425.27	4253241.61	105.50	90.29	0.11		0.100	0.5507	8	74	0.681	
MP Mag ACO	74	316425.42	4253241.48	105.66	90.16	0.13		0.099	0.5207	1	72	0.867	
MP EM GPS	36	316424.85	4253241.67	105.08	90.35		0.03	0.048				0.818	
MP EM ACO	18	316424.51	4253242.14	104.74	90.82		0.00	0.037				0.611	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													1 in X 2 in strap with bolt near surface, not OE
Vehicle Mag EW	34	316389.26	4253246.00	69.50	94.68	0.06	0.05		0.0783	25	67	0.984	
Vehicle EM EW	21	316389.14	4253245.86	69.38	94.54		0.22	0.071				0.696	
Fusion Fit	FUS-51	316389.26	4253245.99	69.50	94.68	0.06	0.08	0.052	0.0780	26	68	0.989	
MP Mag GPS	24	316389.28	4253245.99	69.51	94.67	0.12		0.054	0.0835	30	62	0.891	
MP Mag ACO	70	316389.21	4253246.09	69.45	94.77	0.13		0.055	0.0923	35	56	0.837	
MP EM GPS	29	316389.06	4253245.89	69.30	94.57		0.41	0.070				0.759	
MP EM ACO	9	316388.71	4253245.96	68.94	94.64		0.51	0.074				0.691	
Ground Truth													81 mm Mortar, split in half, 1 in deep
Vehicle Mag EW	42	316417.39	4253246.01	97.63	94.69	0.08	0.07		0.1700	19	22	0.899	
Vehicle EM EW	15	316417.37	4253246.12	97.61	94.80		0.01	0.066				0.945	
Fusion Fit	FUS-151	316417.39	4253246.02	97.63	94.70	0.02	0.07	0.057	0.0980	21	21	0.850	
MP Mag GPS	25	316417.05	4253245.73	97.28	94.41	0.07		0.100	0.5383	61	50	0.895	
MP Mag ACO	75	316417.53	4253246.04	97.77	94.73	0.16		0.077	0.2431	22	18	0.953	
MP EM GPS													
MP EM ACO	14	316417.33	4253246.19	97.57	94.87		0.21	0.070				0.820	
Ground Truth													OE Frag, 3 in X 0.5 in, near surface
Vehicle Mag EW	44	316431.40	4253251.50	111.63	100.18	0.08	0.08		0.2659	1	20	0.931	
Vehicle EM EW	14	316431.25	4253251.74	111.49	100.42		0.00	0.030				0.787	
Fusion Fit	FUS-123	316431.43	4253251.51	111.67	100.19	0.11	0.13	0.087	0.3550	-1	25	0.902	
MP Mag GPS	26	316431.77	4253251.60	112.01	100.28	0.00		0.060	0.1170	-4	24	0.712	
MP Mag ACO	78	316431.69	4253251.48	111.93	100.16	0.12		0.070	0.1887	-9	20	0.903	
MP EM GPS	39	316430.98	4253251.32	111.21	100.00		0.00	0.010				0.120	
MP EM ACO	17	316431.12	4253251.88	111.36	100.54		0.00	0.022				0.378	
Ground Truth													81mm Mortar, nose down, 21 in deep to center
Vehicle Mag EW	40	316414.47	4253253.56	94.71	102.24	0.61	0.09		0.3554	85	80	0.97	
Vehicle EM EW	17	316414.36	4253253.64	94.60	102.32		0.05	0.050				0.939	
Fusion Fit	FUS-32	316414.50	4253253.54	94.74	102.22	0.66	0.36	0.091	0.4140	82	108	0.981	
MP Mag GPS	27	316414.22	4253252.81	94.45	101.49	0.74		0.093	0.4380	76	188	0.879	
MP Mag ACO	77	316414.74	4253253.69	94.98	102.37	0.70		0.093	0.4300	90	105	0.926	
MP EM GPS	33	316414.49	4253253.44	94.73	102.12		0.25	0.046				0.708	
MP EM ACO	15	316414.25	4253253.51	94.49	102.19		0.26	0.049				0.793	
Ground Truth													3 in (71mm) Mortar, no fuze, at 0.25 ft deep, flat EW under Flag
Vehicle Mag EW	43	316422.56	4253257.13	102.79	105.81	0.17	0.06		0.1179	39	255	0.838	
Vehicle EM EW	16	316422.43	4253257.05	102.66	105.73		0.00	0.047				0.757	
Fusion Fit	FUS-31	316422.55	4253257.12	102.79	105.80	0.16	0.07	0.060	0.1180	38	254	0.837	
MP Mag GPS	28	316422.63	4253257.21	102.87	105.89	0.23		0.074	0.2199	26	251	0.85	
MP Mag ACO	79	316422.70	4253257.36	102.94	106.04	0.19		0.054	0.0838	38	258	0.677	
MP EM GPS	35	316422.31	4253256.99	102.55	105.67		0.08	0.058				0.865	
MP EM ACO	5	316422.09	4253257.02	102.33	105.70		0.12	0.062				0.843	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													OE Frag, 3 in X 1 in X 1/8 in
Vehicle Mag EW	38	316402.11	4253260.80	82.35	109.48	0.11	0.08		0.1114	17	132	0.957	
Vehicle EM EW	19	316401.81	4253261.10	82.05	109.78		0.00	0.028				0.764	
Fusion Fit	FUS-34	316402.11	4253260.81	82.35	109.49	0.11	0.17	0.059	0.1090	17	132	0.948	
MP Mag GPS	29	316402.23	4253260.78	82.47	109.46	0.17		0.059	0.1131	22	145	0.946	
MP Mag ACO	85	316402.52	4253260.89	82.76	109.57	0.17		0.061	0.1228	21	140	0.964	
MP EM GPS	31	316401.59	4253260.77	81.82	109.45		0.00	0.017				0.681	
MP EM ACO	6	316401.29	4253260.70	81.52	109.38		0.00	0.017				0.659	
Ground Truth													4.2 in Stokes, broken in half @ 1 ft deep, 8 in long
Vehicle Mag EW	39	316416.87	4253261.01	97.11	109.69	0.34	0.08		0.3000	23	39	0.896	
Vehicle EM EW	18	316416.86	4253261.01	97.10	109.70		0.25	0.074				0.935	
Fusion Fit	FUS-150	316416.88	4253261.01	97.11	109.69	0.29	0.34	0.075	0.2260	24	40	0.875	
MP Mag GPS	30	316416.95	4253261.00	97.19	109.68	0.39		0.083	0.3154	29	42	0.921	
MP Mag ACO	87	316417.20	4253261.03	97.43	109.71	0.37		0.800	0.2778	27	63	0.870	
MP EM GPS	34	316416.97	4253261.03	97.21	109.71		0.15	0.050				0.796	
MP EM ACO	4	316416.48	4253260.89	96.72	109.57		0.14	0.048				0.815	
Ground Truth													OE Frag, 1 in X 1.5 in X 1/8 in at 0.75 ft deep
Vehicle Mag EW	49	316412.21	4253268.22	92.45	116.90	0.16	0.08		0.2430	12	301	0.912	
Vehicle EM EW													
Fusion Fit	FUS-149	316414.89	4253267.14	95.12	115.82	0.20	0.14	0.049	0.0660	-21	90	0.800	
MP Mag GPS	31	316412.15	4253268.26	92.39	116.94	0.16		0.069	0.1759	12	298	0.875	
MP Mag ACO	83	316412.37	4253268.37	92.61	117.05	0.39		0.089	0.3819	30	294	0.518	
MP EM GPS													
MP EM ACO	67	316414.41	4253267.13	94.65	115.81		0.00	0.030					
Ground Truth													3 pieces of OE Scrap, tail fins, 81mm Tail boom, 105mm WH
Vehicle Mag EW	50	316410.99	4253268.86	91.22	117.54	0.72	0.13		1.0882	71	175	0.963	
Vehicle EM EW	24	316410.93	4253269.01	91.17	117.69		0.51	0.094				0.966	
Fusion Fit	FUS-148	316411.05	4253268.89	91.29	117.57	0.75	0.98	0.130	1.1870	71	139	0.968	
MP Mag GPS	32	316411.26	4253268.86	91.50	117.54	0.86		0.154	1.9919	37	116	0.941	
MP Mag ACO	84	316411.20	4253268.87	91.44	117.55	0.68		0.119	0.9218	58	143	0.910	
MP EM GPS	36	316410.93	4253269.05	91.16	117.73		0.96	0.115				0.531	
MP EM ACO	3	316410.64	4253268.92	90.88	117.60		0.90	0.118				0.719	
Ground Truth													2 in angle iron, 11 in long, bent, 0.25 ft deep
Vehicle Mag EW	51	316413.89	4253271.45	94.13	120.13	0.13	0.07		0.1689	9	166	0.783	
Vehicle EM EW	23	316414.72	4253271.19	94.96	119.87		0.12	0.056				0.925	
Fusion Fit	FUS-49	316393.27	4253271.72	73.51	120.40	0.07	0.06	0.048	0.0610	32	337	0.988	
MP Mag GPS	33	316413.94	4253271.42	94.18	120.10	0.08		0.059	0.1122	-9	157	0.846	
MP Mag ACO	82	316414.10	4253271.63	94.33	120.31	0.16		0.064	0.1403	-3	162	0.819	
MP EM GPS													
MP EM ACO	2	316414.74	4253270.86	94.97	119.56		0.16	0.037				0.745	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													81 mm Mortar, nose down, 1.5 ft to base, under the flag
Vehicle Mag EW	16	316441.44	4253217.02	121.67	65.70	0.73	0.10		0.4670	87	191	0.927	
Vehicle EM EW	15	316441.31	4253217.11	121.54	65.79		0.50	0.095				0.637	
Fusion Fit													
MP Mag GPS	38	316441.34	4253216.95	121.58	65.63	0.70		0.093	0.4326	87	90	0.903	
MP Mag ACO	45	316441.30	4253216.34	121.54	65.02	0.70		0.086	0.3506	79	45	0.876	
MP EM GPS	15	316441.71	4253216.82	121.95	65.50		0.00	0.020				0.69	
MP EM ACO	24	316440.34	4253216.96	120.58	65.64		0.08	0.038				0.727	
Ground Truth													OE Frag, 3 in X 2.5 in X 1/ in,4 in deep, under flag
Vehicle Mag EW	8	316402.36	4253211.29	82.59	59.97	0.14	0.09		0.3878	7	72	0.826	
Vehicle Mag EW	9	316402.36	4253211.29	82.59	59.97	0.14	0.09		0.3931	7	72	0.827	
Vehicle EM EW	7	316402.01	4253211.22	82.25	59.90		0.00	0.011				0.078	
Fusion Fit													
MP Mag GPS	39	316402.35	4253211.38	82.59	60.06	0.11		0.089	0.3856	10	62	0.973	
MP Mag ACO	54	316402.28	4253210.93	82.52	59.61	0.17		0.088	0.3723	9	62	0.979	
MP EM GPS	6	316402.55	4253211.95	82.78	60.63		0.08	0.030				0.49	
MP EM ACO	33	316402.29	4253211.04	82.52	59.72		0.40	0.046				0.452	
Ground Truth													81 mm flat EW, 1.5 ft deep, under the flag
Vehicle Mag EW													
Vehicle EM EW	3	316381.90	4253210.97	62.14	59.65		0.01	0.047				0.953	
Vehicle EM EW	4	316381.84	4253211.01	62.08	59.69	0.87	0.10		0.5837	77	356	0.923	
Fusion Fit													
MP Mag GPS	40	316381.85	4253211.04	62.09	59.72	0.82		0.088	0.3670	70	336	0.948	
MP Mag ACO	61	316381.87	4253210.69	62.11	59.38	0.69		0.087	0.3547	89	90	0.958	
MP EM GPS	4	316381.96	4253211.34	62.19	60.02		0.32	0.051				0.684	
MP EM ACO	40	316382.22	4253210.90	62.46	59.58		0.42	0.055				0.618	
Ground Truth													61mm, nose down, 27 in deep, Flag 12 in E, 17 in W
Vehicle Mag EW	3	316370.13	4253210.71	50.37	59.39	0.71	0.08		0.2870	52	319	0.896	
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	41	316370.28	4253210.62	50.51	59.30	0.84		0.090	0.3960	67	333	0.854	
MP Mag ACO	64	316370.33	4253210.46	50.57	59.14	0.74		0.075	0.2332	89	90	0.809	
MP EM GPS	3	316370.12	4253210.70	50.35	59.38		0.39	0.052				0.799	
MP EM ACO	42	316370.57	4253209.86	50.81	58.54		0.39	0.052				0.615	
Ground Truth													81 mm Mortar, nose down, 1.5 ft deep, under the flag
Vehicle Mag EW	31	316375.36	4253221.62	55.60	70.30	0.57	0.09		0.3529	86	340	0.93	
Vehicle EM EW	1	316375.28	4253221.65	55.52	70.33		0.00	0.048				0.859	
Fusion Fit													
MP Mag GPS	42	316375.30	4253221.64	55.54	70.32	0.56		0.088	0.3714	85	336	0.93	
MP Mag ACO	62	316375.22	4253221.39	55.46	70.07	0.94		0.117	0.8703	70	304	0.767	
MP EM GPS	28	316375.07	4253221.33	55.30	70.01		0.00	0.028				0.543	
MP EM ACO	41	316375.84	4253220.85	56.08	69.53		0.30	0.057				0.859	

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													OE Scrap, 2 in X 1 in, 4 in deep, under the flag
Vehicle Mag EW													
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	43	316417.15	4253221.12	97.39	69.80	0.10		0.069	0.1763	13	352	0.966	
MP Mag ACO	86	316412.22	4253220.57	97.45	69.25	0.17		0.070	0.1879	19	3	0.936	
MP EM GPS													
MP EM ACO	29	316416.44	4253221.95	96.67	70.63		0.65	0.105				0.542	
Ground Truth													OE Scrap, 3 in diam, 5 in deep, Flag 21 in S, 18 in W
Vehicle Mag EW	41	316413.58	4253250.43	93.81	99.11	0.10	0.09		0.3314	-4	304	0.989	
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	44	316413.48	4253249.80	93.71	98.48	0.16		0.087	0.3592	-5	309	0.989	
MP Mag ACO	76	316413.92	4253250.62	94.16	99.30	0.16		0.086	0.3459	-7	303	0.988	
MP EM GPS													
MP EM ACO													
Ground Truth													Frag 3 in flat, 0.75 in deep, Flag 18 in S, 15in W
Vehicle Mag EW	37	316405.75	4253245.69	85.99	94.37	0.21	0.10		0.4843	50	63	0.986	
Vehicle EM EW	22	316405.53	4253245.58	85.77	94.26		0.00	0.019				0.594	
Fusion Fit													
MP Mag GPS	45	316405.72	4253245.07	85.96	93.75	0.27		0.096	0.4862	50	61	0.957	
MP Mag ACO	71	316405.87	4253245.69	86.11	94.37	0.27		0.098	0.5052	50	66	0.978	
MP EM GPS													
MP EM ACO	16	316405.37	4253245.43	85.60	94.11		0.00	0.018				0.358	
Ground Truth													Frag 6 in X 1 in X 1/4 in, 6 in deep, Flag 18 in S, 21 in W
Vehicle Mag EW													
Vehicle EM EW	36	316403.89	4253248.75	84.12	97.43	0.17	0.08		0.2279	12	40	0.98	
Fusion Fit													
MP Mag GPS	46	316403.87	4253248.06	83.91	96.74	0.29		0.078	0.2613	16	41	0.741	
MP Mag ACO	72	316404.26	4253248.82	84.50	97.50	0.19		0.071	0.1920	17	41	0.942	
MP EM GPS													
MP EM ACO													
Ground Truth													Frag, 1 in X 2.5 in X 1/8 in, 6 in deep, Flag 12 in E
Vehicle Mag EW	32	316377.46	4253229.98	57.70	78.66	0.20	0.08		0.2766	7	339	0.945	
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	47	316377.56	4253229.96	57.79	78.64	0.20		0.074	0.2177	28	349	0.977	
MP Mag ACO	63	316377.42	4253229.95	57.66	78.63	0.24		0.078	0.2605	8	340	0.971	
MP EM GPS													
MP EM ACO													

Table 6. Survey Analysis of Man-Portable Targets in the GPS-Accessible Area

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													
Vehicle Mag EW	35	316384.88	4253252.55	65.12	101.23	0.15	0.10		0.6120	21	28	0.929	
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	48	316384.82	4253252.54	65.06	101.22	0.21		0.103	0.5883	17	40	0.887	
MP Mag ACO	65	316384.89	4253252.62	65.13	101.30	0.19		0.102	0.5783	18	40	0.965	
MP EM GPS													
MP EM ACO	8	316384.48	4253252.44	64.72	101.12		0.00	0.013				0.503	
Ground Truth													? 1.25 ft long, flat, 9 in deep, under the flag
Vehicle Mag EW	52	316393.80	4253261.67	74.04	110.35	0.23	0.09		0.4171	10	293	0.942	
Vehicle EM EW	20	316394.30	4253261.37	74.54	110.05		0.00	0.047				0.561	
Fusion Fit													
MP Mag GPS	49	316393.88	4253261.69	74.12	110.37	0.25		0.088	0.3674	7	301	0.98	
MP Mag ACO	86	316394.04	4253261.84	74.27	110.52	0.28		0.090	0.3953	13	289	0.940	
MP EM GPS	30	316393.72	4253261.36	73.96	110.04		0.29	0.057				0.641	
MP EM ACO	7	316394.47	4253261.53	74.71	110.21		0.00	0.027				0.809	
Ground Truth													Frag, 3 in diameter, 0.5 ft deep, under the flag
Vehicle Mag EW	47	316421.65	4253267.04	101.89	115.72	0.17	0.09		0.3848	-7	44	0.867	
Vehicle EM EW													
Fusion Fit													
MP Mag GPS	50	316421.66	4253266.99	101.90	115.67	0.18		0.083	0.3086	-1	45	0.965	
MP Mag ACO	80	316422.24	4253267.13	102.47	115.81	0.14		0.078	0.2608	-3	35	0.756	
MP EM GPS													
MP EM ACO													
Ground Truth													Frag, 3 in X 1 in X 1/4 in, 6 in deep, under the flag
Vehicle Mag EW	48	316421.96	4253272.27	102.20	120.96	0.19	0.07		0.1803	69	323	0.879	
Vehicle EM EW	25	316422.03	4253271.96	102.26	120.64		0.00	0.015				0.208	
Fusion Fit													
MP Mag GPS	51	316421.96	4253272.26	102.20	120.95	0.17		0.063	0.1369	67	336	0.985	
MP Mag ACO	81	316422.28	4253272.47	102.51	121.15	0.24		0.083	0.3092	74	359	0.836	
MP EM GPS													
MP EM ACO	1	316421.95	4253272.46	102.19	121.14		0.00	0.012				0.519	

Table 7. Survey Analysis of the Man-Portable Targets in the Woods

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													OE Scrap 3 in X 1 in X 1/8 in, Flag 3 in N, 4 in W
MP Mag ACO	1	316458.09	4253192.03	138.33	40.71	0.22		0.074	0.2188	12	193	0.823	
MP EM ACO													
Ground Truth													OE Scrap, 3.5 in X ?, 0.5 ft deep
MP Mag ACO	7	316436.85	4253207.23	117.09	55.91	0.21		0.086	0.3735	-10	301	0.912	
MP EM ACO	48	316436.28	4253206.59	116.51	55.27		0.15	0.036				0.270	
Ground Truth													OE Frag, 4 in X 1.5 in., 3 in deep, Flat, Under Flag
MP Mag ACO	8	316446.77	4253204.74	127.01	53.42	0.37		0.103	0.5877	87	96	0.891	
MP EM ACO	62	316446.57	4253203.70	126.81	52.38		0.00	0.044				0.077	
Ground Truth													OE Frag, very Hot, 12 in deep, Flag 4 in S, 7 in E
MP Mag ACO	9	316440.54	4253198.02	120.77	46.70	1.16		0.101	0.5597	39	116	0.872	
MP EM ACO													
Ground Truth													OE Frag, 5 in Flat, 5 in deep, Flag 2 in N, 10 in E
MP Mag ACO	10	316439.06	4253177.94	119.29	26.62	0.11		0.103	0.5959	-10	317	0.859	
MP EM ACO	58	316439.38	4253177.55	119.62	26.23		0.00	0.016					
Ground Truth													OE Frag, Flat Chunk, 7 in deep, Flag 8 in S, 12 iun W
MP Mag ACO	11	316424.83	4253189.47	105.06	38.15	0.10		0.070	0.1884	13	288	0.846	
MP EM ACO													
Ground Truth													OE Scrap, 1 in X 2.5 in X 1/8 in, 6 in deep, Under Flag
MP Mag ACO	12	316416.72	4253186.35	96.96	35.03	0.18		0.069	0.1806	13	72	0.850	
MP EM ACO													
Ground Truth													OE Scrap, 4 in size, 4 in deep, 12 in E of Flag
MP Mag ACO	13	316413.31	4253198.56	93.55	47.24	0.14		0.089	0.3809	0	323	0.978	
MP EM ACO	50	316413.35	4253198.53	93.59	47.21		0.24	0.040				0.563	
Ground Truth													OE Scrap, 4 in strip, 6 in deep, 30 in S of flag
MP Mag ACO	14	316367.55	4253177.55	47.79	26.23	0.24		0.077	0.2439	-7	96	0.865	
MP EM ACO	54	316368.64	4253177.62	48.87	26.30		0.00	0.017				0.266	
Ground Truth													OE Scrap, 6 in chunk (2 lb), 6 in deep, under Flag
MP Mag ACO	15	316380.57	4253186.01	60.81	34.69	0.31		0.122	0.9871	5	349	0.574	
MP EM ACO	53	316380.99	4253186.27	61.22	34.95		0.00	0.036				0.797	

Table 7. Survey Analysis of the Man-Portable Targets in the Woods

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													OE frag, 15 in flat, 4 in deep, 6 in SW of Flag
MP Mag ACO	16	316387.32	4253189.30	67.56	37.98	0.27		0.130	1.1858	24	27	0.924	
MP EM ACO	52	316387.44	4253189.37	67.68	38.05		0.16	0.094				0.913	
Ground Truth													OE Frag, 4 in flat, 4 in deep, 4 in SW of Flag
MP Mag ACO	17	316394.48	4253187.97	74.72	36.65	0.24		0.082	0.2997	8	185	0.987	
MP EM ACO													
Ground Truth													Piece of Cable, Near Surface, 3 ft SW of Flag
MP Mag ACO	18	316404.14	4253188.09	84.37	36.77	0.29		0.317	17.3538	63	103	0.785	
MP EM ACO	51	316404.17	4253188.00	84.41	36.68		0.18	0.078				0.668	
Ground Truth													OE Frag, (4 oz), 10 in deep, Flag 8 in S, 10 in W
MP Mag ACO	19	316418.88	4253184.57	99.11	33.25	0.55		0.072	0.2046	46	345	0.763	
MP EM ACO	65	316419.55	4253184.27	99.78	32.95		0.00	0.009				0.028	
Ground Truth													OE Frag, 1 in X2 in X1/8 in, 4 in deep, Flag 4 in S, 10 in W
MP Mag ACO	20	316424.79	4253192.17	105.02	40.85	0.24		0.100	0.5379	-31	147	0.899	
MP EM ACO	63	316425.10	4253192.08	105.33	40.76		0.06	0.037				0.448	
Ground Truth													OE Scrap, 3 in flat, 6 in deep, flag 6 in W
MP Mag ACO	21	316432.08	4253200.14	112.32	48.82	0.15		0.066	0.1578	1	225	0.865	
MP EM ACO													
Ground Truth													OE Frag, 3 in flat, 3 in deep, Flag 10 in NW
MP Mag ACO	22	316434.18	4253205.84	114.42	54.52	0.17		0.076	0.2413	15	269	0.777	
MP EM ACO	49	316432.46	4253206.27	112.70	54.95		0.49	0.072				0.453	
Ground Truth													OE Frag, 3.3 in flat, 4 in deep, Flag 3in NW
MP Mag ACO	23	316438.89	4253205.66	119.13	54.34	0.20		0.084	0.3196	33	142	0.973	
MP EM ACO	47	316438.54	4253205.07	118.78	53.75		0.11	0.039				0.387	
Ground Truth													OE Frag, 25 in flat, 3 in deep, Flag 3 in NW
MP Mag ACO	24	316442.62	4253205.14	122.86	53.82	0.28		0.066	0.1531	6	307	0.634	
MP EM ACO													
Ground Truth													Coiled up cable, 4 in deep, Flag 3 in SE
MP Mag ACO	25	316448.74	4253203.20	128.98	51.88	0.19		0.079	0.2670	5	313	0.850	
MP EM ACO													

Table 7. Survey Analysis of the Man-Portable Targets in the Woods

Survey/Analysis	Survey Target ID	UTM X(m)	UTM Y (m)	Local X (m)	Local Y (m)	Mag Depth (m)	EM Depth (m)	Size (m)	Moment	Inclin. (deg)	Azim. (deg)	Fit Quality	UXO Supervisor, Field Comments
Ground Truth													OE Frag, 1 in X 3 in X 1/8 in, Flag 7 in SE
MP Mag ACO	26	316454.12	4253202.57	134.36	51.25	0.21		0.071	0.1945	42	322	0.701	
MP EM ACO													
Ground Truth													Frag, 1 oz, 6 in deep, Flag4 in E, 1 in N
MP Mag ACO	27	316456.17	4253204.19	136.41	52.87	0.23		0.068	0.1727	-2	32	0.842	
MP EM ACO													
Ground Truth													OE Frag, 8 in deep, flat, Flag 4in S, 2 in E
MP Mag ACO	28	316458.57	4253199.60	138.81	48.28	0.42		0.082	0.3042	-1	144	0.909	
MP EM ACO													
Ground Truth													OE Frag, 3.5 in X1 in X1/4 in, near surface, Flag 3 in N, 2 in W
MP Mag ACO	29	316450.96	4253186.14	131.19	34.82	0.18		0.075	0.2333	-23	109	0.844	
MP EM ACO													
Ground Truth													Ball of wire, 4 in deep, Flag 6 in N
MP Mag ACO	30	316467.71	4253181.35	147.94	30.03	0.25		0.080	0.2792	43	22	0.866	
MP EM ACO													
Ground Truth													OE Frag, 4.5 in flat, 4.5 in deep, Flag 4 in E, 6 in N
MP Mag ACO	31	316437.54	4253176.01	117.78	24.69	0.24		0.075	0.2261	12	108	0.869	
MP EM ACO	57	316438.22	4253175.75	116.46	24.43		0.00	0.029				0.229	
Ground Truth													OE Frag, Near Surface, Flag 2 in S, 4 in W
MP Mag ACO	32	316422.06	4253172.74	102.30	21.42	0.21		0.048	0.0596	89	218	0.662	
MP EM ACO													
Ground Truth													OE Frag, 2 in deep, flat, Flag 2 in E, 7 in S
MP Mag ACO	33	316427.18	4253180.85	107.42	29.53	0.14		0.070	0.1841	-20	311	0.763	
MP EM ACO													
Ground Truth													Can, 3 in diam, 4 in long, 5 in deep, Flag 8 in N, 8 in W
MP Mag ACO	34	316435.00	4253181.35	115.23	30.03	0.21		0.049	0.0633	75	11	0.930	
MP EM ACO	59	316435.18	4253180.19	115.41	28.87		0.00	0.004				0.008	
Ground Truth													Coil of 1/4 in Cable,10 in deep, Flag 12 I S, 17 in W
MP Mag ACO	35	316418.22	4253179.12	98.46	27.80	0.41		0.125	1.0500	-6	105	0.928	
MP EM ACO													
Ground Truth													OE Frag, 4 in diam, 8 in deep, Flag 2 in S
MP Mag ACO	36	316390.15	4253189.85	70.38	38.53	0.23		0.073	0.2085	10	249	0.928	
MP EM ACO	64	316390.45	4253190.34	70.69	39.02		0.00	0.013				0.109	

Table 8. Results of Target Recovery in the Man-Portable Survey Area.

Item	Seed Targets	71-mm Mortar	81-mm Mortar	4.2-in Mortar	25-lb Frag Bomb	5-in Rocke t	OE Scrap	Non-OE Scrap
Number Recovered	18	1	14	1	1	1	43	11

The recovered OE scrap items included shrapnel, tail fin assemblies, spent fuzes, etc. Non-ordnance related materials included pieces of iron or steel such as angle iron, bolts, and hardware or coils of wire or cable. Not all of the recovered ordnance items were completely intact. Some were split, broken, or significantly bent. Several ordnance items were challenged with 1-in shape charges. None of the recovered items were fuzed nor contained explosive fills. All recovered materials (except the seed ordnance) were certified by the UXO supervisor as free of explosives contamination and disposed of by a commercial waste hauler.

5.2 Data Assessment and Technology Comparisons

Performance evaluation criteria include system detection sensitivity, accuracy of location and depth predictions, navigation system performance, and operational and ergonomic efficiency of the man-portable units.

5.2.1 ***Detection Sensitivity*** The ability to detect targets primarily depends upon the sensitivity of the sensors, the completeness of the survey coverage, and the signal to noise ratio in the survey data. The MMS system uses the same sensors as the *MTADS* vehicular system. The sensor horizontal separation and height above the ground are identical to the vehicular system and data sampling rates are such that the sampling density of the two systems are approximately equivalent. The signal to noise ratios in data taken by the two systems are also similar. Carefully laid out surveys conducted with the MMS provide similar detection and performance capabilities to the vehicular system. Data from the two systems is effectively equivalent, interchangeable, and indistinguishable.

The EMMS, as it was configured for the L-Range demonstration, could be deployed with either one meter square coils or with 0.5 X 1.0 meter coils. Only the latter system was used in this demonstration. These coil systems, specially manufactured for this application, supposedly had the same design as the individual units in the vehicular system. On a simple scaling basis, based upon the areas of the send and receive coils and a 50% overlap of transmitters in the vehicular system, one would expect that the individual half meter instrument might record 6 times lower signal strengths than the vehicular system for the same test object. While this would lower the sensitivity of the EMMS relative to the array, we did not expect that this would significantly limit our ability to detect (particularly shallow) targets because the array system is extremely sensitive for small shallow targets. In reality, the new coil systems were not completely equivalent to the units in the *MTADS* array. Measurements with electronic test equipment showed somewhat different system

set up parameters, and measurements on a test stand using standard objects confirmed the lower sensitivity. In addition, as deployed at the L-Range the EMMS using the wheel mounting system supplied with the instrument, placed the lower coil 0.4 meters above the ground. The vehicular *MTADS*, depending upon the suspension system being used on the tow vehicle, typically deploys the coils about 0.25 meters above the ground. Figure 9 shows a comparison of a small part of the L-Range survey area taken from the vehicular and man-portable surveys. Note the difference in display scales. The EMMS, as it was used in this demonstration, is 10-15 times less sensitive than the vehicular *MTADS*. The absolute differences are also a function of the size and depth of the test objects. The EMMS, as it was configured for this demonstration, provides data sample densities equivalent to, or slightly higher, than the vehicular system. The deployment of the GPS antenna high above the coils on the EMMS (Figure 1) introduces an additional noise source in the data. When the system traverses over rough areas side-to-side rocking motions can easily displace the antenna by half a meter horizontally from the center of the coils. Because the system is behind the operator, this motion is often not noticed or controlled. The acoustic navigation system transmitter does not significantly interfere with the EM sensor. The transmitter is typically deployed at the center of the upper EMMS coil.

The ability to detect a target also obviously depends upon the ability to deploy the sensor. In this demonstration much of the survey area was in the woods and much of the area was left relatively uncleared to test the ability of the man–portable systems to survey under realistic conditions. The EMMS coils were deployed in the narrow (0.5 meter wide) orientation and 0.25 meter survey lanes were used to maximize coverage. The area coverage in the open areas was relatively good, as shown in Figure 7. Our coverage in the wooded areas was, in retrospect, unsatisfactory. Relatively large areas were left unsurveyed. Some of the area was effectively inaccessible because of system design limitations. The difficulty of using the EMMS in tight areas, combined with excessive backpack loads, difficulty in following lane layouts, poor site survey management, and operator frustration all contributed to performance.

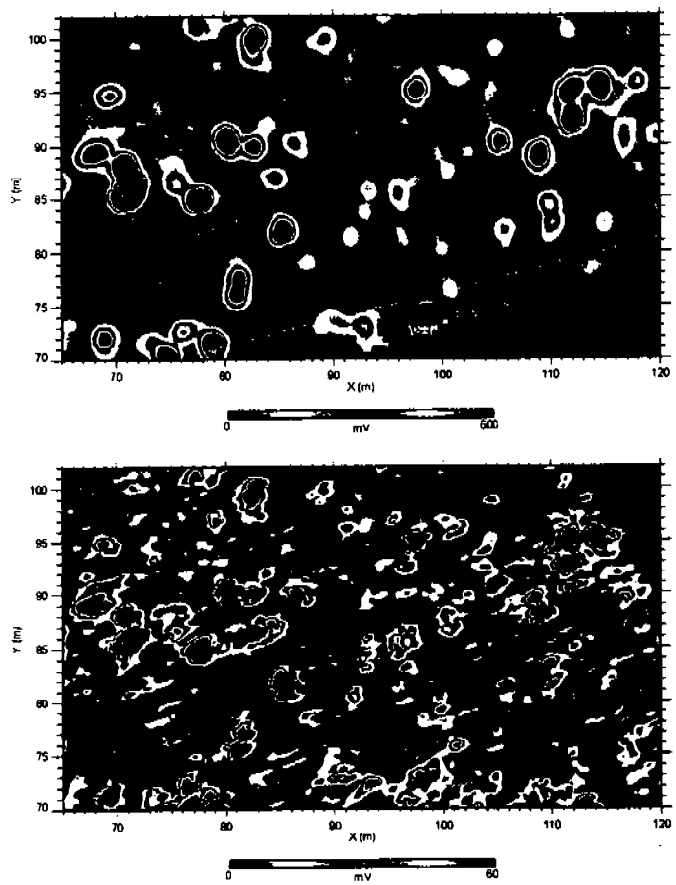

Figure 9. EM surveys from the L-Range. The upper image is from a vehicular *MTADS* survey. In the lower image the EMMS 0.5 X 1.0 m coils were used in a survey guided by the acoustic navigation system.

The survey performance in the

woods could have been improved by either conducting a second survey in an orthogonal direction to fill in some of the missed areas or by using the bush hog to clear remaining brush and undergrowth before a resurvey. In reality, however, the primary lesson learned from the EMMS deployment at the L-Range was that more development was required.

5.2.2 Missed Targets In this demonstration system performance was measured primarily against the seeded targets and secondarily, we considered the performance of the man-portable systems relative to the vehicular *MTADS*, the performance of the man-portable systems using GPS versus acoustic navigation, and finally the performance of the MMS compared to the EMMS. As shown in Tables 5, 6 and 7, the MMS detected all the targets that were characterized using the vehicular magnetometer array. With one exception, all the seed targets were detected and analyzed in each of the surveys that covered their positions. Seed target, T-14, was not detected by the EMMS because it fell in a missed survey area.

In the EMMS survey using GPS navigation, 14 targets were missed that were characterized in vehicular EM survey, and in all the magnetometer surveys. Coverage by the EMMS in the open range area was good. In all cases the targets were missed because, either there was no measurable signal in the EM data, or the signal-to-noise ratio placed the targets below the limits required for analysis. These results are summarized in Table 6. In general, in EM data a target described by a dozen data points with a signal-to-noise of >3 are sufficient to designate a target and converge to a fit using the analysis algorithm (although the fit quality may be minimal for this limited amount of data). The navigation error created by the rocking GPS antenna created an additional noise source which tended to smear out a target signal and make it very ragged (see Fig. 9). In some cases this created a situation in which the fit would not converge, in other cases it was difficult to recognize a target signal in a relatively noisy background.

Performance evaluation on the entire range area can be made by comparison of the MMS and EMMS surveys using the acoustic navigation system. The MMS survey contains 21 targets that were undetected in the EMMS survey. Of the 21 missed targets, 9 targets (in the woods) were in areas missed by the EMMS survey. In the remainder of the cases, the EM signal was undetectable or too weak for analysis.

5.2.3 Target Location Figure 10 shows a plot of the performance of the various systems in locating the positions of the seed targets. The ground truth positions are those measured by the surveyor when the targets were buried. The results are summarized in Table 9.

The location and depth prediction capabilities of the vehicular *MTADS* systems were equivalent to the system performance in many prior demonstrations. Targets are typically located to within 10-15 cm with the magnetometer array and 20-25 cm with the EM array. Depth predictions of the *MTADS* DAS based upon magnetometer data are typically within the volume of the UXO item. Depth predictions using the point dipole algorithm with EM data are less reliable. The vehicular magnetometer survey and the MMS/GPS survey results demonstrate that the MMS can provide equivalent field performance to the vehicular system.

Table 9. Errors in location and depth predictions for the seed targets at the L-Range

Survey	Vehicular Mag/GPS	Vehicular EM/GPS	MMS/ GPS	MMS/ Acoustic	EMMS/ GPS	EMMS/ Acoustic
Horizontal Error (cm)	11	21	11	43	26	60
Depth Error (cm)	5	29	5	11	(*)	(*)

(*) At this time the fitting algorithms in the DAS were not calibrated with the new coil signals to provide meaningful depth predictions.

5.2.4 The Acoustic Navigation System Use of the acoustic navigation system degrades the location accuracy over the GPS system. With careful use, however, position uncertainties of 0.25 meter with the acoustic navigation system, can be used to hold target location capabilities to 0.5 meter. In conducting acoustic navigation surveys in open areas, site dimensions should not exceed 200 feet in any direction. Antenna locations should surround the perimeter of the site and it is helpful to have an antenna centrally located within the site. System performance degrades when there is a high background noise interference. Even wind blowing through knee-high grass raises the operational threshold of the antennas (to exclude noise) to a level that noticeably degrades system performance.

A single antenna setup was used to survey the wooded part of the L-Range. This setup worked satisfactorily even though many of the antennas were not directly (line of sight) visible to each other because of elevation changes or because trees and brush seriously obstructed visibility. A careful initial setup is required. Three of the antenna positions should be at known coordinates and it is advised that system performance be evaluated against a known position within the survey before undertaking a survey. Even though this system is difficult to use, it is the best available (non-GPS) automated navigation/location system that can be used to conduct digitally mapped UXO surveys.

5.2.5 System Ergonomics

Mechanically, the MMS performed satisfactorily in the L-Range demonstration and the system performance as a UXO survey tool met all system design specifications. However, as outlined in Sections 2.3.1, we felt that the system was not appropriate for transition to commercial applications where it would be used in much more demanding conditions by much less skilled operators. We undertook system modifications, as described below, to ergonomically improve the system so that it could be successful in commercial applications.

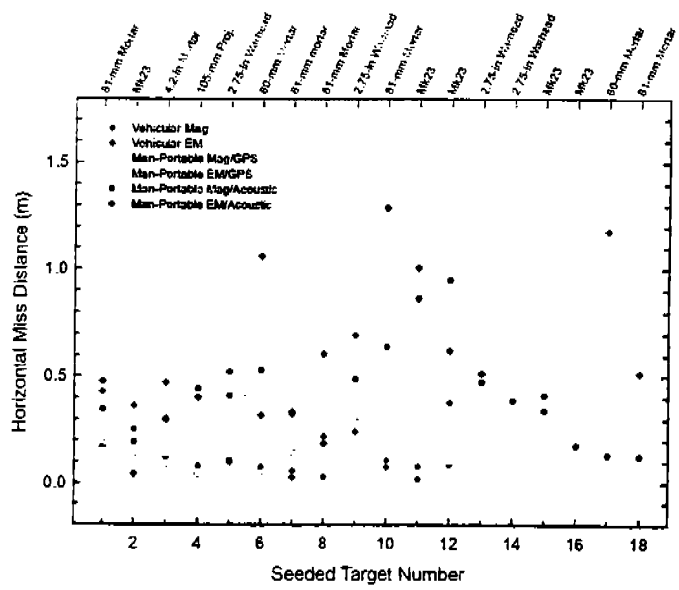

Figure10. Comparison of the horizontal location accuracies for the seed targets at the L-Range.

The EMMS system performance was disappointing on several levels. Cost constraints in system development and integration led to use of existing equipment that was too heavy and bulky for backpack applications. The system design, based upon a narrow coil on a trailing cart supported by high wheels, had a poor usability. The electronic performance of the newly-purchased coil systems proved to be too insensitive for dependable UXO surveys for either shallow or deep targets. The poor ergonomic design and limiting electronic design frustrated the performance in the demonstration. A complete redesign of the EMMS was undertaken in preparation for the final demonstration. See Section 6 of this document.

6.0 Final System Prototype Modifications

6.1 Component Changes in the Final Prototypes

Following the L-Range demonstration we felt that an additional round of system development and a new system demonstration was required to produce *MTADS* man-portable adjuncts that would be directly commercializable. ESTCP supported this development.[14] In addition, a modest amount of funds remaining on the NRL/Blackhawk Geometrics CRADA were devoted to this project.[21] As described in later sections, the final prototypes were demonstrated at field surveys at the Jefferson Proving Ground in the summer of 2000.[19]

6.2 Subsystem Component Upgrades

Based upon the original Man-Portable Program Development Plan we reconsidered each of the subsystem components from a requirements and performance point of view. We considered the impact of these decisions on the MMS and EMMS overall system requirements and performance expectations. Only one significant change was made in the initial system performance specifications. Given the difference in performance of the vehicular EM array, and what would become the final man-portable EM array, it was unrealistic to attempt to develop the DAS so that man-portable and vehicular EM survey data could be used interchangeably. Ultimately the DAS was modified to separately accept and fit either vehicular or EMMS data, but no attempt was made to create a conversion that would make the two data sets equivalent.

6.2.1 Cabling The cables and connectors used to interconnect the various system components (batteries, sensors, navigation components and data logger) as used at the L-Range demonstration were too large in number and not rugged enough for sustained field work. We redesigned the cabling for both prototypes. The number of cables was reduced. The new cables have improved strain-relieved connectors, and they are designed for connection to interface plates in the new backpacks. Spares were manufactured or purchased for each cable.

6.2.2 Batteries Each individual component of the man-portable prototypes was delivered by its manufacturer with an individual battery pack. The capacity of these battery packs ranged from several days for the acoustic location system to1.25 hours for the EM-61. In operation, this meant that we had to stop to change the EM battery every hour while carrying other heavy long-lived batteries. New battery requirements were established and battery performance tests were

undertaken to design new battery packs minimizing carry weight while allowing one hour performance with a 25% excess capacity. Some of the battery performance tests are included in the Appendix. These measurements were done to assure that the chosen battery systems could meet the requirements under all expected field conditions. Delivery of the new EM coils (see below) required carrying a new heavy lead acid battery to power the coils. This new battery was placed on the new system cart as discussed below. Battery chargers and batteries were purchased that would allow day long continuous use. Packing and shipping cases for these items were purchased or constructed.

6.2.3 Data logger The modifications we originally made to the standard Geometrics 858 data recorder (Figure 3) greatly increased its flexibility and usability with the MMS and the EMMS. One remaining shortcoming required modification. The operator did not have real-time display access to the quality of the GPS fix. For the Demonstrations at the L Range. fix quality requirements were accommodated by planning to work in times of good satellite visibility. In a real-world environment this would be unacceptable. We arranged with the manufacturer to carry out additional modifications to the data logger to display the GPS fix quality and to sound an alarm when the quality drops below Fix Quality 3. The Geometrics 858 data logger, as modified for this program, is now commercially available from Geometrics for purchase, or from their equipment rental pool.

6.2.4 The MMS Sensor Cart For the L Range Demonstration we designed a magnetometer cart with mounts for the antenna/transponder location with an emphasis on ease of use and minimizing weight. The cart performed acceptably for the tests. The tests were not in difficult terrain, however. Subsequent analysis showed that a major increase in strength and reliability could be obtained with a small weight penalty.

We redesigned, engineered, and manufactured a new magnetometer cart with improved ruggedness and a better ergonomic design. The engineering drawings for the new magnetometer cart are included as an appendix on the CD-ROM included with this report. The new cart, shown in Figure 11 set up for a GPS survey, is constructed of a combination of fiberglass and plastic components. The wheels have been placed side by side between the sensors. This design works better in tight spaces and on more rugged and uneven terrain. The hood, as shown in Figure 12, covers and protects the sensors and the antenna and allows the system to slide through grass and low brush without snagging the cart or sensors. The height of the handles and the weight that the operator has to carry in his hands represents a considerable ergonomic improvement from the earlier design. The complete system can be operated by a single operator for an extended time without tiring. With the hood the MMS weighs 52 lbs, without the hood the weight is 38 lbs. The total backpack weight is 18 lbs (GPS antenna).

6.2.5 The EMMS Cart In the case of the EM-61, deploying the prototype with the wheels provided by the manufacturer positions the transmit coil 40-cm above the ground. Since the measured EM signal falls off as $1/r^6$, a large increase in signal (and thus sensitivity for relatively shallow objects) could be obtained by lowering the sensor. Following delivery and acceptance of the new EM sensor (see below) we designed and build a new EM cart to support the system. It is more rugged, more pitch and roll stable, provides a better weight balance in front and behind the wheels to minimize carry weight for the operator, and incorporates a new design that put the sensors

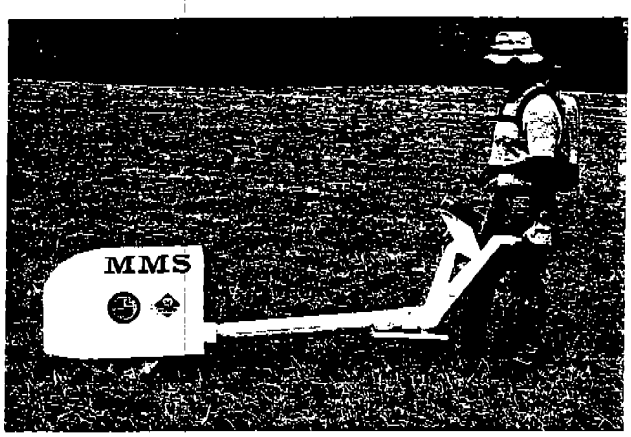

Figure 11. The MMS is shown deployed with the protective hood and the GPS navigation hardware.

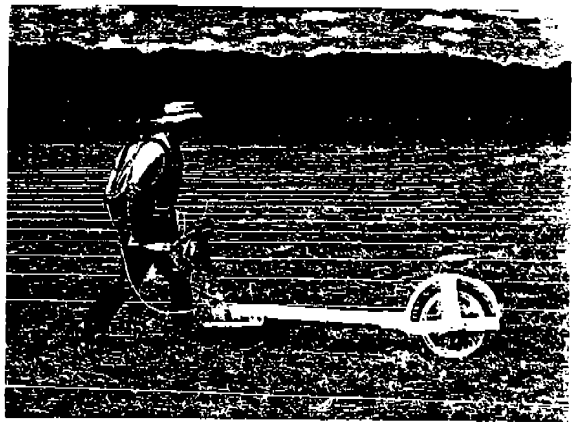

Figure 12. The MMS is shown as deployed on Area 3 at the Jefferson Proving Ground.

in front of the operator.

The engineering drawings for the new EM carts are included as an appendix on the CD-ROM included with this report. Sensor trays were designed so that the sensor can be mounted with the long dimension across the track, Figure 13, or pointing down the track, Figure 14. The new sensor coils require the use of a heavy lead-acid battery for power. The battery is mounted in different positions, depending upon the orientation of the coils, to balance the weight load over the wheels. The weight that the operator has to lift is not large, however, the weight of the total system including battery, cart, and coils, and antenna is 110 pounds. Pushing this sized load proved to be difficult when terrain conditions were very rugged, or when the survey area was deep mud. These operational issues are discussed in more detail in the presentation of results for the JPG demonstration. The system battery was oriented and positioned to minimize signal from the plates at the receive coils. The newly designed backpack and system components allow the operator to carry all components in a 31-lb backpack. The system is designed to collect data for one hour

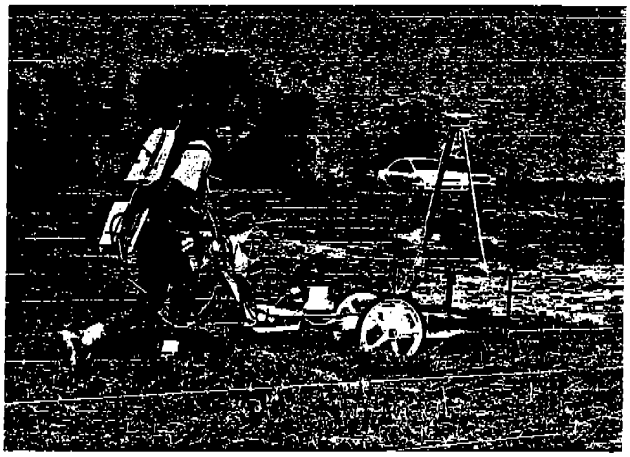

Figure 13. The EMMS is shown with the digital inclinometer and the GPS navigation system as deployed at the Jefferson Proving Ground

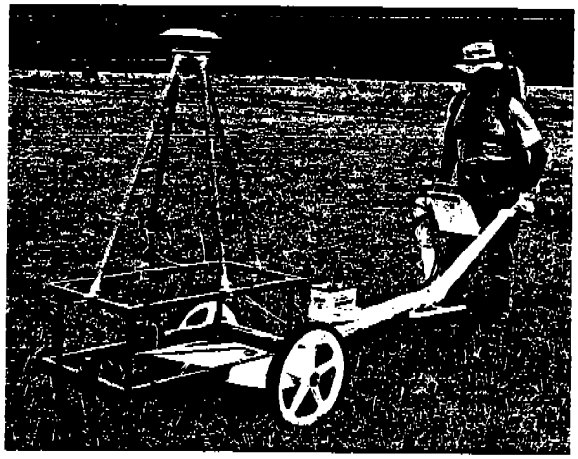

Figure 14. The EMMS is shown with the coil mounted with the 0.5-m dimension pointing down the survey track.

before battery change out. The MMS and EMMS, when deployed with the acoustic navigation system, has the ceramic transmitter deployed immediately above the sensors. The transmitter does not interfere with either the magnetometers or the EM sensors. The transmitter is shown deployed on the EMMS in Figure 15.

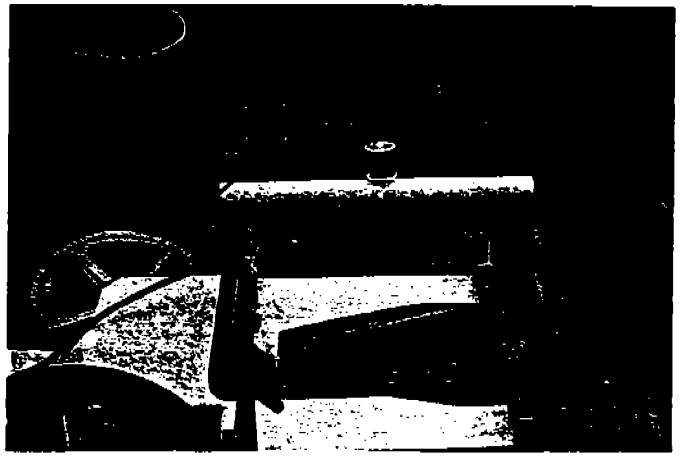

Figure 15. The EMMS is shown deployed with the Chemrad acoustic navigation transponder.

6.2.6 The New EM Coil After reviewing the performance characteristics of the EMMS in the L-Range Demonstration with the manufacturer, a new 0.5 X 1.0 m coil system was developed by Geonics for our use. The coil underwent extensive testing at our Blossom Point facility which resulted in further fine tuning of the coil performance specifications. The present EMMS coil is much more sensitive than any prior EM-61 type system that we have tested. This improved sensitivity was accomplished by making many changes in the system design. Both the transmit power and the signal detection sensitivities were improved by making numerous changes in the coil design, the power delivery system, and the detection electronics. Some of these design changes are proprietary to the manufacturer. However, the coil as currently deployed on the EMMS, can now be purchased as a standard product from the manufacturer. The increased transmission power has required a substantial increase in battery capacity to power the system. We tested several lead-acid deep discharge batteries before specifying the present system. Since the batteries must be recharged after one hour of use, the correct choice was considered important. Based upon the battery performance tests we chose the Powersonic Model 12330 (33 amp-hours). A battery charging system was purchased that will allow us to simultaneously charge 5 batteries which are needed to continuously operate for a full day.

6.2.7 The DAS The *MTADS* data analysis system underwent an upgrade to accommodate the new developments in this program and other ongoing ESTCP UXO programs. The new EM coil system (Figures 13-15) was extensively characterized on a test stand to determine its response to standard metal test objects. In addition, the coil was used to resurvey the Blossom Point Magnetic Test Range for comparison with earlier systems. The absolute sensitivity of the 0.5 X 1.0 m coil system is compared to the vehicular array and to the coil system used for the L-Range demonstration in Figure 16. The absolute value of the relative sensitivities is mildly dependent on the depth, size, and composition of the test object, but in all cases, the new coil has an equivalent or greater detection sensitivity than a single unit of the vehicular array. These measurements and results are described in an internal report titled "New Coil calibration Report" which is included in Appendix D. The current DAS has switches to allow target analysis of survey data with algorithms tailored for the new coil. As part of the shakedown process for the new MMS and EMMS instruments new data sets were taken in our test pit for a wide range of inert ordnance items. These are incorporated into our ordnance library.

7.0 JPG-V Demonstration Approach

The FY-2000 demonstrations at the Jefferson Proving Ground were jointly sponsored by ESTCP, AEC, US Army Engineer R&D Center , and NEODTD.[19] The survey test areas consisted of three 1-hectare prepared sites. The demonstration approach was built around a scenario intended to evaluate technologies that might address the particular demands of the Kaho'olawe Island cleanup. Both inert UXO, OE scrap, and magnetic soils/rocks were incorporated into the test. Two of the three sites took advantage of naturally occurring magnetic soil deposits. These were augmented by soil/rock samples from Hawaii. The third site was geologically relatively benign. Three demonstrators were invited to participate using active electromagnetic sensors. These included the most recent *MTADS* variant of the Geonics EM-61, a variant of the Geophex GEM Sensor, and the Geonics EM-63 sensor. Each demonstrator was required to conduct digitally-mapped geo-referenced surveys and to conduct target analyses on site as though concurrent remediation would take place.

NRL, using magnetometer arrays (both vehicular and man-portable), independently conducted magnetometer surveys of each of the 1-hectare sites. These data were preprocessed to create geo-referenced mapped data files that were provided to each of the other demonstrators and are included in Appendix F of this document. All demonstrators were invited to incorporate the magnetometer data into a sensor fusion analysis and to provide these analyses to the US Army Engineer R&D Center within 30 days of their site visits.

All demonstrators worked to a common Demonstration Test Plan issued by NEODTD.[24] This Plan is included as Appendix F to this document. Ten types of inert ordnance were included, varying in size from 20-mm aircraft-fired projectiles to 155-mm howitzer projectiles. Examples of these items were provided to each demonstrator for study and calibration prior to their site surveys. Demonstrators were told that emplaced inert ordnance was degaussed. The non-UXO items were not described (or provided) other than to state that they were realistic OE scrap.

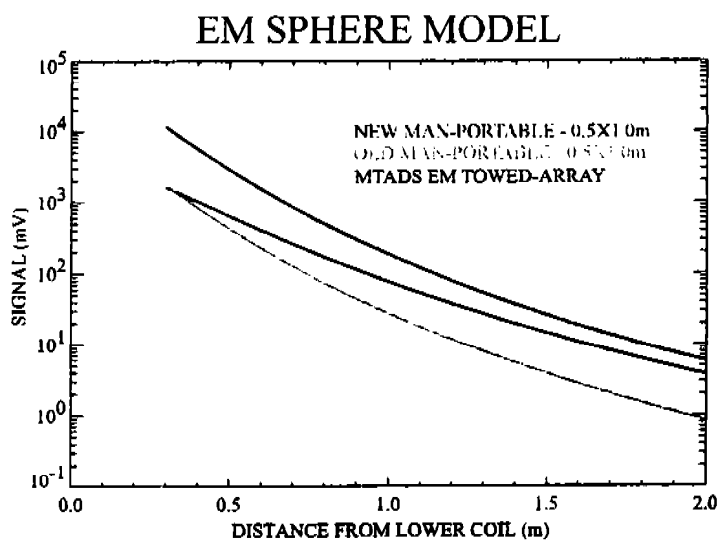

Figure 16. Relative response of various EMMS coil systems to a 4-in test sphere. The responses are for the lower coil of each system. The Towed-Array response is for a single coil of the three coil array.

7.1 JPG-V Performance Objectives

It was understood that the onsite EM surveys and analysis products would be evaluated on the basis of cost/production

rates, UXO detection rates, target location accuracy, UXO identification ability, and a probabilistic categorization of detected targets as UXO or not-UXO. Additionally, each demonstrator was asked to make recommendations in the target lists as to whether an item should be dug, or could be confidently left in the ground. Two independent analyses were to be submitted based upon the assumption that 20-mm projectiles either were, or were not, present.

Demonstrators were invited to provide additional analyses from their joint post processing of magnetometer and EM data. The evaluation criteria were assumed to be similar to those applied to the on-site analyses.

7.1.1 NRL Man-Portable System Objectives All sites were surveyed with the man-portable *MTADS* EM adjunct (the EMMS). All sites were surveyed with the *MTADS* vehicular magnetometer array. Site 3 only, was surveyed using the man-portable *MTADS* adjunct (the MMS). Our demonstration and evaluation of these instruments was the primary objective of this report. Additionally, we wished to compare their performance with the vehicular *MTADS* and with the other (more complex) EM sensor technologies.

7.1.2 NRL Data Analysis/Classification Objectives All EM data analyzed on site employed the *MTADS* DAS upgraded to carry out 3-β UXO classification target analyses based upon developments in ESTCP Program 199812.[17] Additional test pit measurements were made upon some of the inert UXO test items provided to each of the demonstrators when the mod or variant of the ordnance was different from those in our signature library. The objectives of the on-site analyses were to use this classifier and realistic size thresholds in the data analysis to discriminate between UXO and OE scrap. Therefore, this report also describes a blind test of the performance of the 3-β classifier.

7.2 JPG-VSampling and Analysis Procedures

7.2.1 3-β Classification of EM Data Many of the UXO items used at the JPG test site are very similar in size. Neither the magnetometer nor the EM analysis/classification routines can distinguish between them. These fitting uncertainties are further complicated by the noise sources introduced into the data by conditions of the survey field and the process of taking the data. One of the reporting requirements was to predict ordnance type. In general, our predictions of ordnance type were grouped into categories of similar sized items, i.e. 57/60-mm, 76/81-mm, 105mm/4.2-in, 152/155-mm, etc. In some situations, predicted sizes fell between more disparate items such as 60/81mm mortar, etc. Our type predictions attempted to reflect these uncertainties. It has been our experience that it does not matter at all to the UXO remediator whether we can distinguish among similar ordnance sizes. In general, size predictions resulting from combined EM and magnetometer analyses are more precise and reliable than those resulting from EM data alone. Data such as that shown in Figure 17 was used in making EM classifications. For instance, the dashed line was a trial value to use for minimum size threshold for UXO declarations assuming that 20-mm ordnance was not present. Based upon noise levels in the field data and complexity of some of the anomaly signatures, ultimately a 57-mm lower size threshold of 37 mm was chosen. Targets fitting to sizes smaller than 37 mm were classified as confidence level 5 or 6 based upon their beta coherence

values and other visual information about the target. Similar plots for other UXO were used as training data for classification decisions.

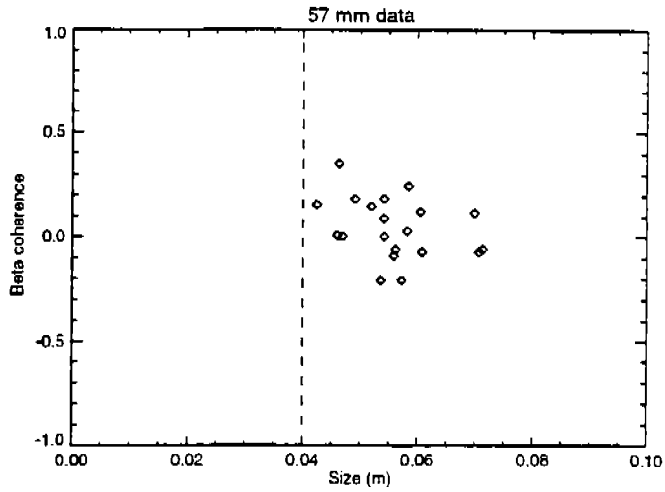

Figure 17. Plot of a parameter based upon the beta fitting values vs predicted size for 20 measurements of a 57-mm UXO target in a field survey.

An additional reporting requirement[24] asked that we rank each target (among all those reported) as to its relative probability of being UXO or "not-UXO." Neither our EM nor the magnetometer analysis tools lends itself to a mathematical probabilistic classification. In our EM data analysis the results of the 3-β classifier fit was used to predict UXO or "not-UXO," and to make decisions about which one of the 6 "confidence categories" to assign to the analysis. Our probabilistic ranking was reduced to binning all targets into these 6 probability categories. Categories 1-3 are classified as ordnance, category 1 includes items with the highest confidence ordnance assignment. Category 3 has the lowest confidence UXO assignment, but is more likely ordnance than not. Categories 4-6 are the mirror image scrap categories with 6 designated as most confident assignment as scrap. Assignments were made generally based upon the 3-β assignments.

An exception to this strictly 3-β based assigned scoring was the assignment to either confidence category 5 or 6. We recommended digging all targets with confidence classifications of 1-5. In some cases a 3-β classification of 6 was raised to 5 because we felt it was too risky to leave a specific item undug. It was felt that the spatial resolution available from the 1-meter coils might lead to mis-classifying a target if, for instance, a nearby clutter item became part of the analysis object. In later analyses, in numerous instances, anomalies analyzed as single targets in the EM analysis broke up into multiple targets or clusters of items in the magnetometer survey.

*7.2.2 **Joint Magnetometer and EM Analysis*** In the joint analysis which included the magnetometry data, the *MTADS* baseline point dipole fitting algorithm was applied to each anomaly declared in the EM data set. Additional targets were fit and/or declared based upon anomalies that did not appear (or were rejected for analysis) in the EM data set. In assigning decisions in the joint analysis, the 3-β EM classification was accepted as a starting point. Modifications were made to the 3-β classification when it was clear that additional information was present in the magnetometry signature. In a few instances magnetometry targets were selected that were not visible in the EM data. These were mostly deep targets and some may be associated with geological formations. If a magnetic anomaly fit an ordnance profile in the magnetometry data, and if it was deep enough that it might be undetectable in the EM survey, it was chosen for digging. Some EM classifications were changed based upon the magnetometry analyses. These fell into two categories. Targets with strong remnant moments and/or inverted signatures were classified as OE

scrap and usually reduced to category 6 (Don't Dig). EM anomalies that appeared as multiple targets in the magnetometry analysis were reclassified based upon their magnetometry analysis. A few targets were reclassified in the joint analysis based upon their predicted size in the magnetometry analysis if it was felt that they clearly did not fit size thresholds required to be UXO.

7.3 JPG-V - Physical Setup and Operation

The JPG-V demonstration was conducted under the guidance of the JPG Work Plan and in accordance with the NRL Demonstration Work Plan. Each of these documents is included in Appendx F on CD-ROM attached to this report. NRL was allotted a time slot of 27 August-6 September to conduct the demonstration. On 27 August, the equipment was deployed to the site. All data analysis equipment was unloaded into the office trailer and set up for operation. Field radios and rechargeable batteries were setup in the office trailer and plugged in for recharging. The survey equipment was unloaded into the equipment storage area about 0.75 miles away and the EMMS was assembled.

Area 3 was staked, gridded and surveyed with the EMMS on 28 August. Area 1 was staked, gridded, and surveyed with the EMMS on 29 August. Area 2 was similarly completed on 30 August. The US Army Engineer R&D Center and NEODTC site managers maintained a detailed log of on site labor and production rates for the conduct of all surveys and analysis work. This log is included as an Appendix titled JPGsurveyLabor.xls. The setup and survey production rates are summarized in **Table 10**, below. The labor hours in the separate senior supervisor labor category in the JPGsurvey Labor.xls file were repartitioned into the appropriate working labor categories as shown below.

Table 10. Production rates associated with various JPG-V survey and analysis activities.

Survey	Area 3 (Man Hours)	Area 2 (Man Hours)	Area 1 (Man Hours)	Total (Man Hours)
Stake & Grid	9.5	9.2	10.3	29
EMMS Survey	18	21.5	19.3	59
EMMS Analysis (On Site)	20.5	18.8	23	62.5
Target Reports				23.5
MMS Survey	20			20
Vehicular Mag Survey	4.75	3.5	4.5	12.8
Clean Up/ Pack Out				15

Following completion of the EMMS surveys, two laborers from the local casual labor market were brought onboard to assist in conducting the man-portable MMS survey of Area 3, to flag for

the vehicular *MTADS* magnetometer survey of all three areas, and to participate in the cleanup and pack out. This allowed Dr. Bell and Dr. Nelson to participate in the final analysis and preparation of target reports for the EMMS surveys. On August 28-30, Dr. Nelson and Dr. Bell exclusively supported the EMMS field survey operations. Mr. Puc, for the most part, supported the data handling operations, taking the raw data from the field surveys, setting up the survey sites, and preprocessing and entering all the data into the survey files. He additionally preprocessed all MMS and vehicular EM survey data on site and participated in preparation of the EMMS target reports and dig images that were on-site deliverables for this project. Mr. Koppe supported all *MTADS* field operations. On 28 August and the morning of 29 August, Dr. McDonald supported the EMMS stake and gridding operations and the remainder of the time conducted the data analysis and target picking and preparation of EMMS data deliverables which were presented to the sponsor on 1 September.

7.3.1 EMMS 3-β Survey Products Area 3 was surveyed first. Prior to surveying, a 12 gauge wire was stretched 1.0 meter outside the east and west site boundaries to use for position and timing calibration. The first-order survey point adjacent to the site was used for the GPS base station for this survey (and for all other surveys). The site was gridded with wooden stakes at 1.5 meter intervals along the east and west site boundaries. Twine was pulled between stakes to define survey lanes. Lanes were surveyed at 0.5 meter separations. Figure 18 shows the EM anomaly image for Area 3. The analyzed target numbers are shown adjacent to the anomalies. The return from the calibration wire is shown outside the east and west site boundaries.

All analyses are provided as target tables on spreadsheets in Appendix G. The spreadsheets contain the target analyses that were provided to the sponsor on site for the EM surveys and by Email before the one month deadline for the joint EM and magnetometer analyses. There are four spreadsheets for each of the three sites. Data were analyzed twice, once assuming that 20-mm projectiles were present, and a second time assuming that 57-mm rifle grenades were the smallest UXO threat on site. Also included in the spreadsheets are ground truth summaries provided by Dr. Ernie Cespedes at the ESTCP Symposium and Workshop. The spreadsheets contain ground truth entries only for targets intentionally buried on the three areas. Subsequent to completion of all other activities, it was understood that the additional targets claimed by more than one of the demonstrators would be dug to determine the source of the observed anomalies. The EMMS survey results for Area 3 are provided below as summaries of the information in the worksheets in Tables 11 and 12.

7.3.2 The MMS-EMMS Joint Analysis Survey Products The magnetic anomaly map of the Area 3 vehicular survey is shown in Figure 19. Survey analysis spreadsheets are also provided in Appendix G for the results of the joint magnetometer and EM survey analyses. Again, ground truth, to the extent that it was available, is appended to the spreadsheets. The results for Area 3 are summarized below in Tables 13 and 14.

7.3.3. Comparison of the MMS and Vehicular Surveys Area 3 was surveyed with both the vehicular *MTADS* and the MMS system. Independent baseline target analyses were carried out on each data set. These analyses are compared in spreadsheets included in Appendix F of this report.

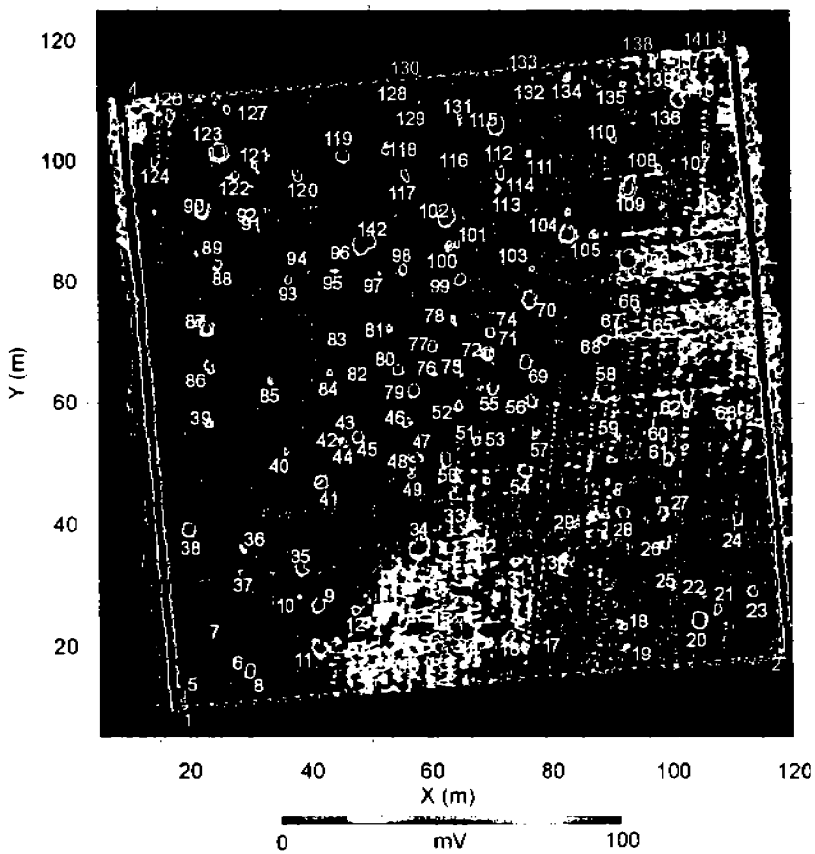

Figure 18. EM anomaly image of the Area 3 EMMS survey. Target numbers are shown beside the anomalies.

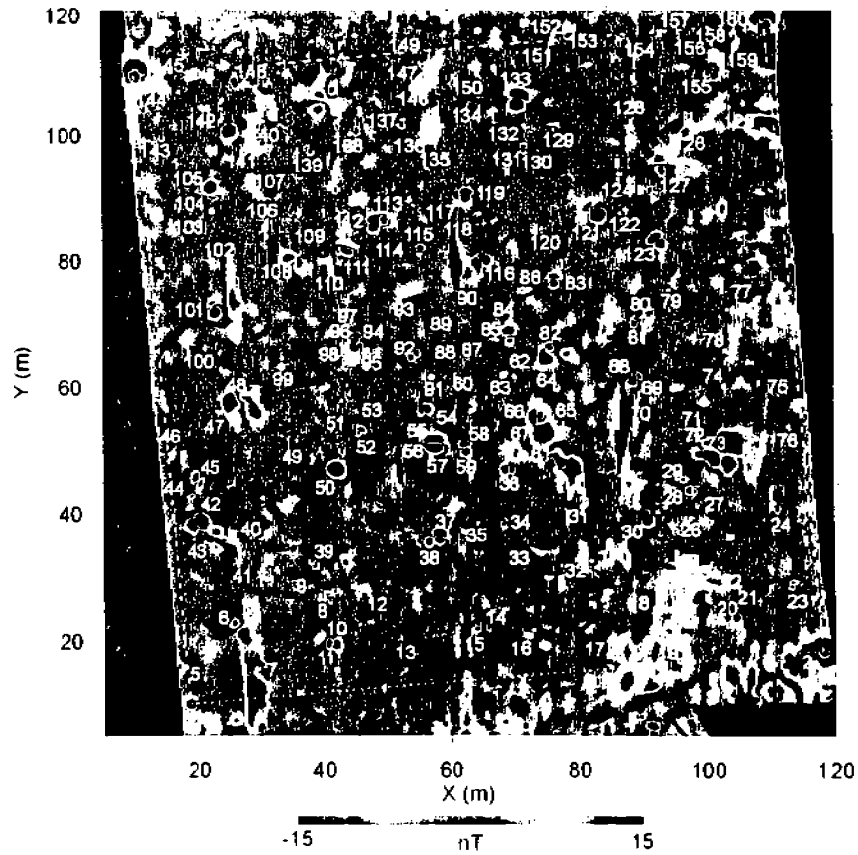

Figure 19. Magnetic anomaly image of Area 3 resulting from the vehicular *MTADS* survey. Target numbers from the joint analysis are shown.

Table 11. Area 3, EM Survey , 3–β Classification, Assuming 20-mm Projectiles are Present

Targets Declared	Targets Buried	UXO Detections	UXO Not Detected	Correct UXO Classifications	UXO Misclassified	UXO, Correct Type Assignment	Incorrect UXO Type Assignments	OE Scrap Correct Classification	OE Scrap Correctly Not Dug
134	55 20 UXO 35 OE	19	1 (81-mm)	13 of 19	4 (20-mm) 1 (60-mm) 1 (155-mm)	7 of 13	81mm as 105mm/4.2in 81mm as 2.75in 76mm as 57/60mm 105mm as 76/81mm 152mm as 105mm/4.2in 60mm as 76/81mm	11 of 29	4 of 29

Table 12. Area 3, EM Survey, 3-β Classification, Assuming 20-mm Projectiles are Not Present

Targets Declared	Targets Buried	UXO Detections	UXO Not Detected	Correct UXO Classifications	UXO Misclassified	UXO, Correct Type Assignment	Incorrect UXO Type Assignments	OE Scrap Correct Classification	OE Scrap Correctly Not Dug
134	55 16 UXO 39 OE	15	1 (60-mm)	12 of 15	1 (60-mm) 1 (81-mm) 1 (155-mm)	7 of 12	81mm as 105mm/4.2in 81mm as 2.75in 76mm as 57/60mm 105mm as 76/81mm 152mm as 105mm/4.2in	21 of 34	14 of 30

Table 13. Area 3, Joint Magnetometer and EM Survey, Joint Analysis Assuming 20-mm Projectiles are Present

Targets Declared	Targets Buried	UXO Detections	UXO Not Detected	Correct UXO Classifications	UXO Misclassified	UXO, Correct Type Assignment	Incorrect UXO Type Assignments	OE Scrap Correct Classification	OE Scrap Correctly Not Dug
154	55 20 UXO 35 OE	20	0	15 of 20	4 (20-mm) 1 (60-mm)	13 of 17	81mm as 57/60mm 76mm as 2.75in/81mm 105mm as 2.75in 60m as 76/81mm	20 of 33	10 of 33

Table 14. Area 3, Joint Magnetometer and EM Survey, Joint Analysis Assuming 20-mm Projectiles are Not Present

Targets Declared	Targets Buried	UXO Detections	UXO Not Detected	Correct UXO Classifications	UXO Misclassified	UXO, Correct Type Assignment	Incorrect UXO Type Assignments	OE Scrap Correct Classification	OE Scrap Correctly Not Dug
154	55 16 UXO 39 OE	16	0	14 of 16	1 (60-mm) 1 (81-mm)	12 of 16	81mm as 57/60mm 76mm as 2.75in/81mm 105mm as 2.75in 60m as 76/81mm	28 of 37	21 of 37

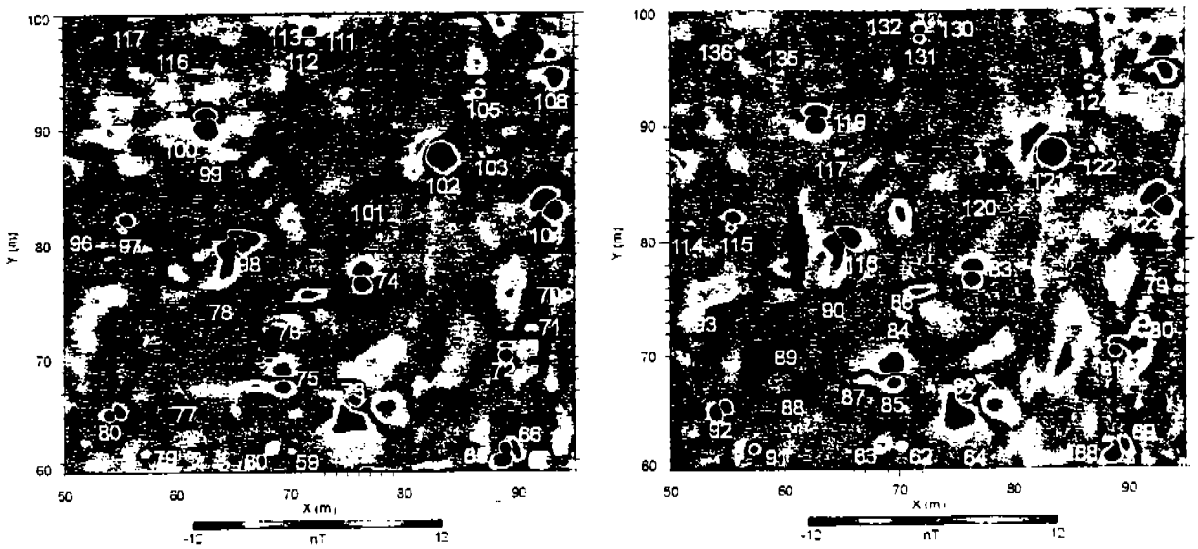

Figure 20. Magnetic anomaly image of part of Area 3. The MMS survey is shown on the left and the vehicular *MTADS* survey is shown on the right.

Figure 20 shows comparisons of images of mapped data files of a typical selected section of Area 3. Table 15 shows by way of comparison, that vehicular survey of Area 3 required 4.75 man-hours while staking, gridding and surveying of Area 3 with the MMS required 20 man hours of labor. The relative efficiencies of the vehicular survey was not fully demonstrated because well over half of the vehicular survey time was occupied in turns at the ends of the very short survey lanes on this one hectare site. The small missed area at about X=60, Y=80 meters in the vehicular survey involved maneuvering around a tree. This area was more effectively surveyed with the MMS. The noise levels in the MMS data are slightly higher than in the vehicular data, but not sufficiently so to significantly affect the quality of the analysis. Information from the two surveys is effectively interchangeable.

7.4 JPG-V Performance Assessment

7.4.1 Performance Data The surveys of Areas 1 and 2 reveal regions that are significantly more geologically active. The motion-induced noise in the EM image (Figure 18) results from surveying across shallow furrows dating from when the area was in cultivation prior to its use as a range. The EMMS and *MTADS* magnetometer survey images of Areas 1 and 2 are shown in Figures 21-24. The magnetic soil deposits distributed across much of Area 2, or in the ravines in Area 3, do not significantly interfere with the EM survey data. Their effect on the magnetometry data is much more pronounced. Target analysis of magnetometry data in these areas is much more tedious, requiring display of small areas with constant resetting of offsets and detrending during the fitting of individual targets. In general, with very careful analysis, 10 nT anomalies can be fit in regions with geological magnetic soil offsets of 200 nT. Small targets, such as 20-mm projectiles or 60-mm mortars, at depth, have a higher probability of going undetected in these areas, however.

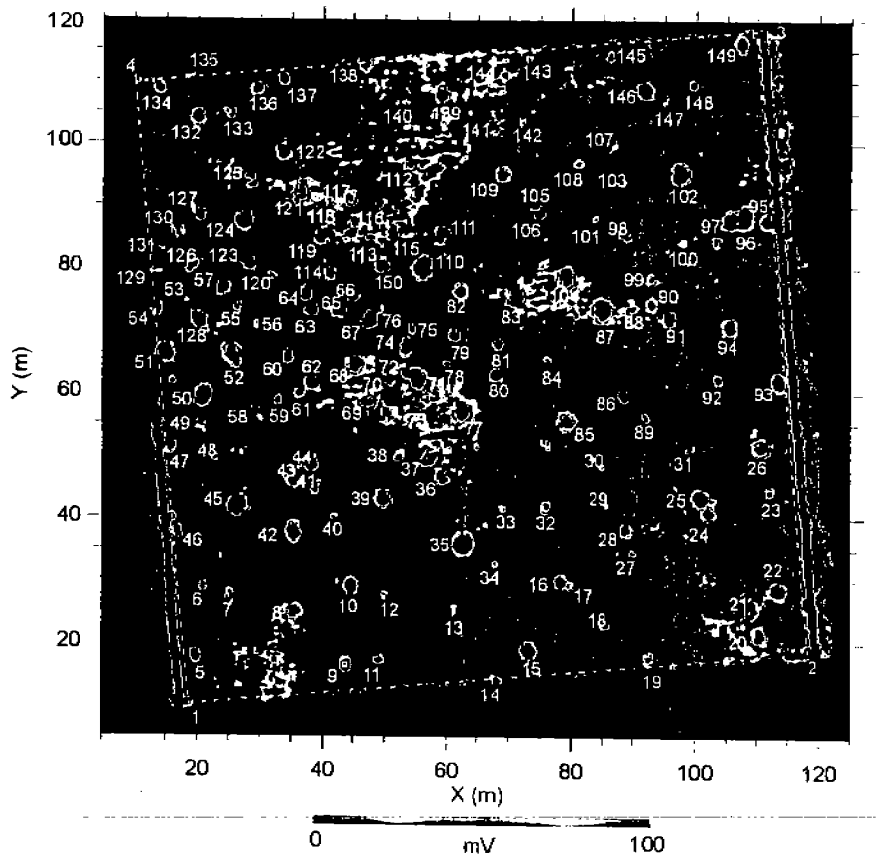

Figure 21. EMMS Survey of Area 1 at the Jefferson Proving Ground.

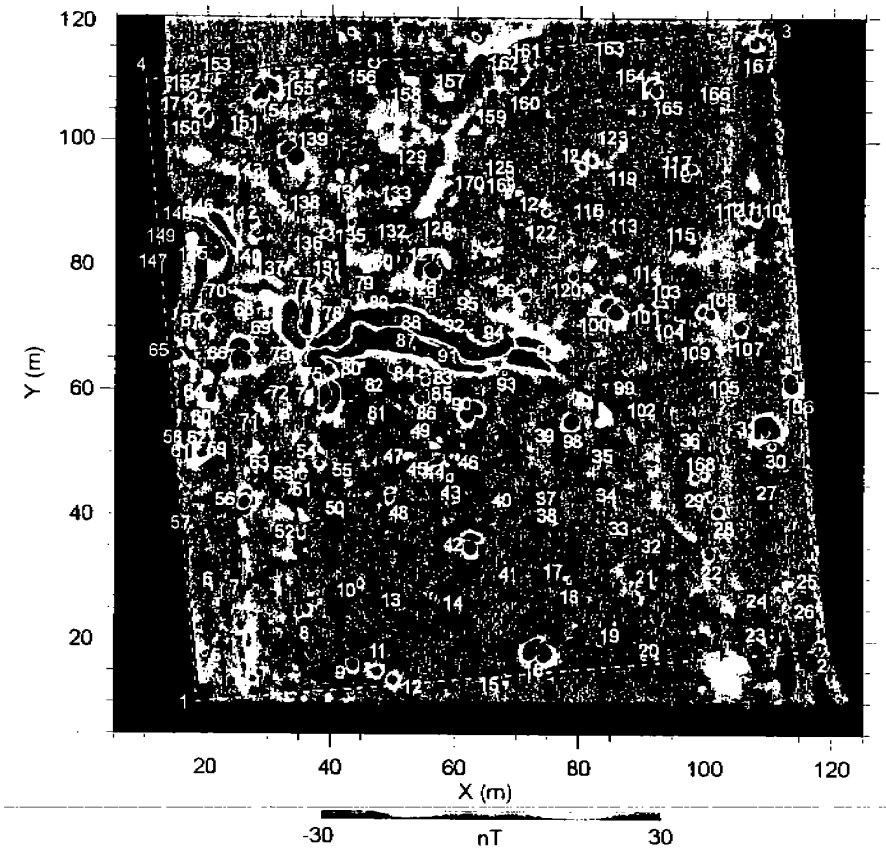

Figure 22. Vehicular *MTADS* magnetometer survey of Area 1 at the Jefferson Proving Ground.

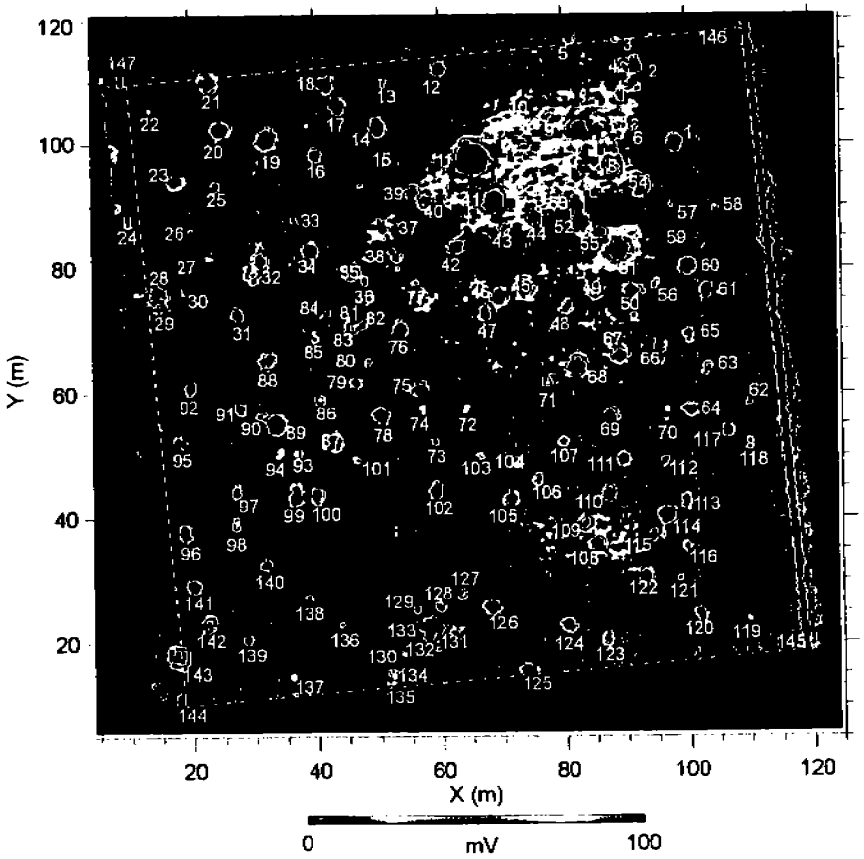

Figure 23. EM anomaly image from the EMMS survey of Area 2 at the Jefferson Proving Ground.

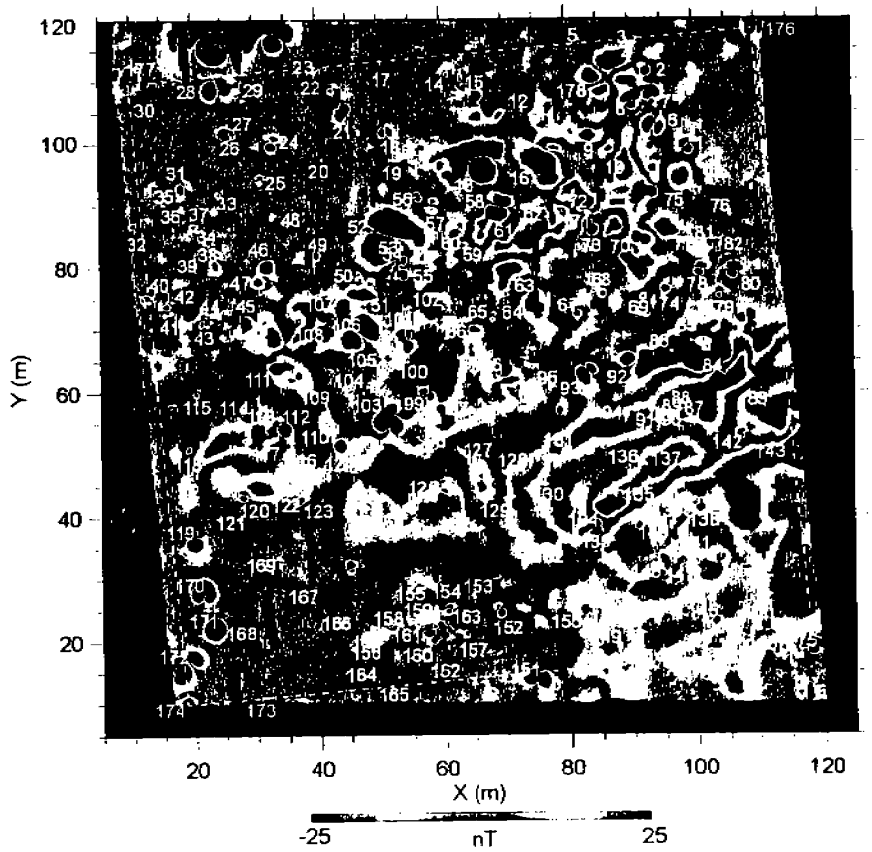

Figure 24. Magnetic anomaly image from a vehicular *MTADS* survey of Area 2 at the Jefferson Proving Ground.

7.4.2 *Data Assessment and Technology Comparisons*

Detection Sensitivity Detection probability statistics for Area 3 are summarized in Tables 11-14, and are summarized for all three sites in Table 15 which shows a comparison among the three demonstrators with data taken from the presentation of Dr. Cespedes at the ESTCP Workshop. NRL data are as turned in on-site, assuming 20-mm projectiles are not UXO. The absolute detection sensitivities of the NRL EM and magnetometer systems are similar. The EM sensors have a greater sensitivity for small shallow objects and the magnetometer array is more sensitive for large, more deeply buried objects. The EM sensors also detect small shallow objects more efficiently because, using the overlapping 1-meter coils, surface coverage approaches 100%. It is possible for small objects, such as 20-mm projectiles to pass between the magnetometers undetected, even with a 25-cm separation. Separations of 0.5-m or more would lead to more misses than detections for these small objects. To some extent, the detection sensitivity is also a function of target picking. Saturation picking will detect more metal objects, but without an efficient discrimination tool for analysis, many more objects will have to be dug using this approach. All three demonstrators appeared to have sufficient detection sensitivity to detect the full range of UXO items buried at the depths of this demonstration. The differences in detection efficiency of Surveyors B and C, relative to the *MTADS* is largely a matter of the number of targets chosen for declaration.

Table 15. Surveyor Performance at the JPG-V Demonstration*

Probability of UXO Detection

	NRL	*Surveyor B*	*Surveyor C*
Area 1	*95.3%*	*100%*	*90.7%*
Area 2	*96.7%*	*100%*	*93.3%*
Area 3	*100%*	*100%*	*90%*
Overall	*96.8%*	*100%*	*91.3%*

Objects Declared

Total Objects in Dig Sheet			
	NRL	*Surveyor B*	*Surveyor C*
Area 1	*149*	*177*	*144*
Area 2	*147*	*236*	*206*
Area 3	*142*	*202*	*105*

* This Table was adapted from Dr. Ernie Cespedes

Missed Targets Assuming that the sensors have sufficient sensitivity to detect these UXO challenges, the number of missed targets reflects three factors: the signal-to-noise and spatial resolution in the data, the number of targets chosen for declaration, and experience in extracting target signatures from geological and scrap clutter interferences in the data. While the EM sensors are much less subject to geological interferences from magnetic soils, the spatial resolution of the magnetometer sensors is significantly higher, allowing better unclustering of adjacent or nearby targets. This unclustering (or cleanup of complex target signatures) is a time consuming data processing step that does not readily lend itself to software automation. The time expended in this data cleanup is in part responsible for the accuracy of the *MTADS* in precisely locating and estimating sizes of UXO targets and in detecting deep targets in complex fields with nearby clustered targets. The relatively low EM coil sensitivity of the EMMS system used in the L-Range surveys led to both missed targets and relatively poor location accuracy. This has been overcome by the new EMMS system. The data from this man-portable unit is at least as high fidelity as the *MTADS* vehicular EM survey data.

Target Locations As described above, precision in location of targets is a strong function of data cleanup during analysis. However, our use of carefully time-stamped data, the highest precision GPS navigation systems, and high data sampling rates are equally critical in obtaining target data fits with sufficient information to precisely describe the target. In general, the location accuracy of the target fitting routines, from a vehicular *MTADS* magnetometer survey is about 10-15 cm while the EM array typically produces fits that are accurate to 15-25 cm. The lower accuracy is, in part due to the larger coil size of the EM array and the lower data density relative to the magnetometer data. The accuracy of the magnetometer fitting routines in predicting target depth are typically in the range of 20-30% of the absolute depth. Very shallow targets often have higher errors and deep targets are often fit to within 10% of their depth. The *MTADS* baseline EM fitting routine typically gives much poorer depth fitting accuracy than the magnetometer fitting algorithm. We have found that the 3-β fitting algorithm applied to EM data typically provides depth estimates that are more accurate than the baseline point-dipole EM fit, though they remain less accurate than the magnetometer depth predictions.

In Table 16 below, we compare the performance predictions of the vehicular *MTADS* magnetometer array, the MMS, and EMMS surveys with the JPG Ground Truth (provided by Ernie Cespedes for Area 3). To provide a greater range of information, we also independently compare the position and depth predictions of the MMS and EMMS surveys with the predictions resulting from the *MTADS* vehicular survey and analysis. The latter comparisons might reveal any systematic bias or significant random errors in the location accuracy of the provided ground truth.

The location and depth predictions of the vehicular *MTADS* survey compare favorably with the provided ground truth and fall within the expected accuracies of our system. There was neither any detectible systematic position bias, nor any significant single target location discrepancy. Likewise, the location accuracies and depth predictions of the MMS and EMMS surveys and analyses were within the expected accuracies of the systems. The performance of the MMS and the vehicular *MTADS* magnetometer array were statistically indistinguishable.

Table 16. Position and Depth Discrepancies Among the Magnetometer and EM Surveys Compared to the JPG Ground Truth*

Survey	ΔX-Y (m) Relative to JPG Ground Truth		ΔDepth (m) Relative to JPG Ground Truth		ΔX-Y (m) Relative to *MTADS* Mag		ΔDepth(m) Relative to *MTADS* Mag	
	Average	Median	Average	Median	Average	Median	Average	Median
EMMS	0.18	0.18	0.16	0.12	0.21	0.16	0.21	0.16
MMS	0.16	0.11	0.15	0.11	0.13	0.09	0.09	0.05
MTADS Vehicle Mag	0.16	0.09	0.13	0.08				

* Both UXO and Clutter Targets are included in this analysis.

Classification Performance Differentiating UXO from OE scrap and metallic clutter has been the primary objective of all our *MTADS* development programs for the past three years (except for the development of the man-portable *MTADS* adjuncts). We have participated in several ESTCP[17] and SERDP[24] programs (and have been cooperating and interacting with other development efforts) designed to create and evaluate data analysis approaches to improve UXO discrimination efficiency.

This test at JPG was the most stringent and comprehensive evaluation of the latest analysis tool for the EM system, the 3-β analysis algorithm.[17] The approach was originally developed for the *MTADS* EM array with the overlapping 1-meter coil systems. It was adapted for this development and this demonstration with the single unit 0.5-meter coil system. With the vehicular array we have typically conducted two orthogonal surveys of the same area to get the maximum possible shape information for the processor. In the present instance, the smaller coil provides higher resolution data, and because of it $0.5m^2$ total area, effectively radiates each object with a much wider range of incidence radiation vectors on each survey lane. Using the EMMS, we have taken data on closely spaced lanes to additionally assure overlap and high data density. Under these circumstances we have surveyed the three areas only once, and have used the processor to extract classification information. The classification results are shown in **Table 17.** Level 1 targets were most confidently assigned as UXO, level 2 are less so. Level 3 are doubtful, but more likely UXO, than not. Level 4 are declared as more likely not UXO. Level 6 is most likely not UXO, and we recommend that these targets do not need to be dug. Level 5, we feel is likely not UXO, but are not confident enough to leave them in the ground.

In this demonstration, we would describe the 3-β classifiers performance as a limited success. One classification metric is the ROC curve as presented by Dr. Cespedes at the ESTCP workshop. An adaptation of one of his tables is presented in Figure 25. These are plots of correct UXO declarations as a function of the number of non-UXO targets picked using the probability (increasing numerical confidence factor) as the running index. These plots show that Area 3 was

Table 17. Classification of the targets from the JPG surveys.*

Classification Confidence Level	AREA 1				AREA 2				AREA 3			
	3-β Analysis		Joint Analysis		3-β Analysis		Joint Analysis		3-β Analysis		Joint Analysis	
	20-mm	No 20-mm	20-mm	No 20-mm	20-mm	No 20-mm	20-mm	No 20-mm	20-mm	No 20-mm	20-mm	No 20-mm
1									22	18	20	17
2									17	6	15	9
3									14	11	25	14
4									12	8	13	8
5									28	19	42	21
6									41	72	39	85
Total Declarations									134	134	154	154
Dig/ Don't Dig									93/ 41	62/ 72	115/3 9	69/ 85

* Ground Truth Data were not available for Area 1 and 2 when this document was completed.

the easier site on which to classify targets. Reaching 90% correct UXO declarations on Area 3 required picking only about 60 non-UXO targets. On Area 1more than 80 targets had to be picked (and on Area 2 more than 90 targets had to be picked) to recover 90% of the seeded UXO.

A more stringent test of a target classifier is its ability to recognize OE scrap and metal clutter as metallic targets that can be left in the field. Considering Tables 11-14, using the 3-β classifier at the relatively benign Site 3, we correctly classified 11 of 29 or 21 of 34 OE scrap targets (depending upon whether 20-mm targets were included). This allowed us to correctly recommend leaving only 4 of 29 or 14 of 30 OE scrap targets in the field (again depending upon the presence of 20-mm UXO objects). In the ordnance column, we correctly classified 13 of 19, or 12 of 15 anomalies as UXO depending upon the disposition of the 20-mm projectiles. The 20-mm projectiles were the most difficult UXO targets to correctly classify.

Combining the EM and magnetometer survey data in a joint analysis improved both the classification and dig decisions by about a factor of two, while simultaneously decreasing the number of ordnance items that would be left in the field after digging. See Tables 13 and 14. The correct classification of UXO objects in the joint classification was similar to that using the EM data alone because these classifications were still primarily based upon the 3-β analysis. Most of the improvement in classification in the joint analysis was based upon the improved spatial resolution in the magnetometer data and the ability of the magnetic dipole analysis to recognize strong remnant moments.

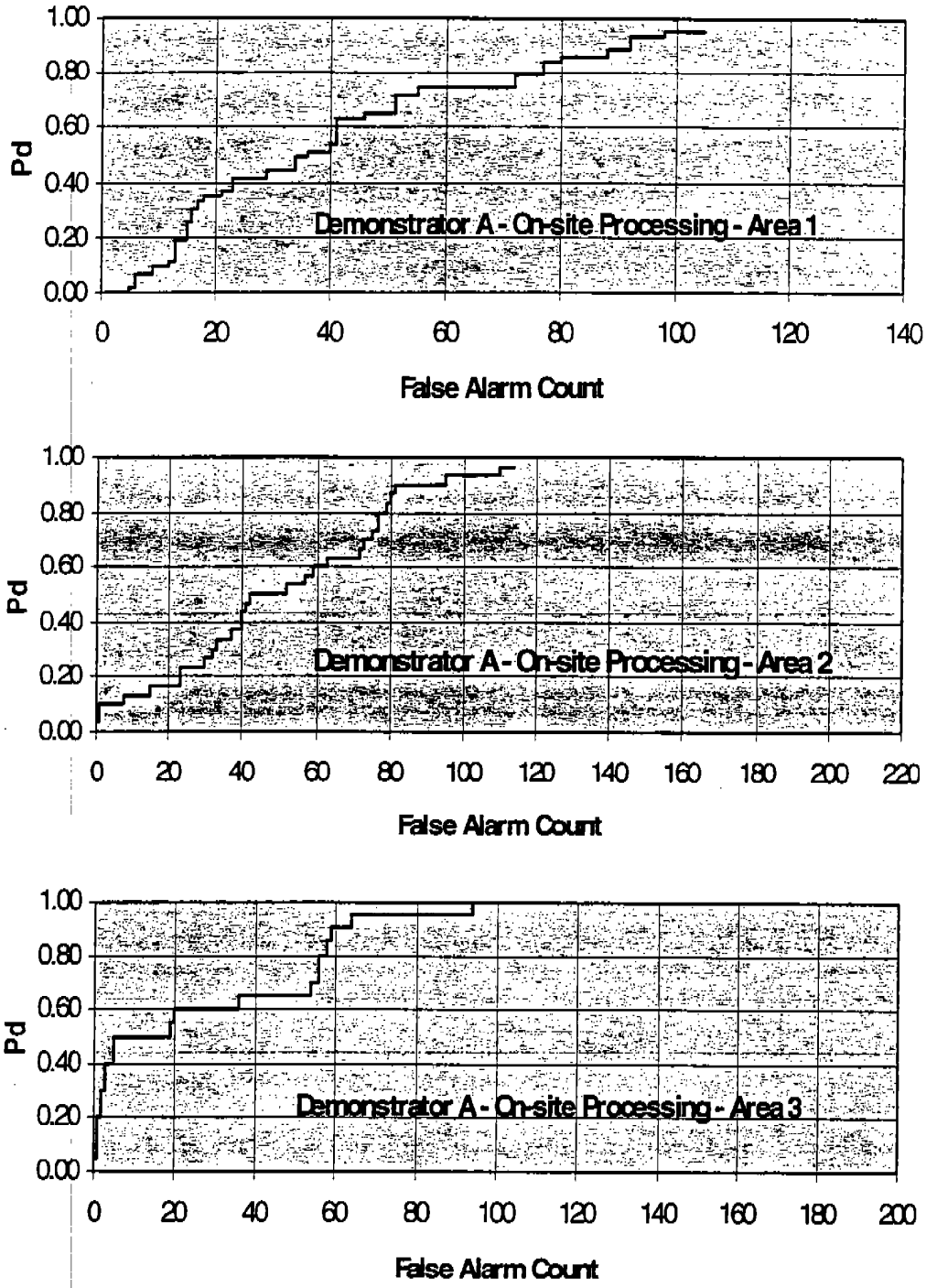

Figure 25. ROC curves for the EMMS survey and analysis of the three Demonstration Areas at the Jefferson Proving Ground. (Figure is adapted from Ernie Cespedes).

Where time and resources will allow, using both sensor platforms and a joint target analysis will provide improved target detection and recovery. It is problematical whether it will lower digging costs, overall. The improved classification capability in a joint analysis tends to be offset by the tendency to pick more targets using multiple survey data sets.

7.5 Cost and Production Rates

Assuming deployments similar to those at JPG-V, the *MTADS* deployment costs are about $10K per day, on site. The production rate of the MMS and EMMS system are about 1.5 hectares per day, in open areas using GPS navigation. The MMS can be used with less labor costs as it is much less labor intensive to operate. Production rates would likely decrease and costs would likely increase by a factor of 2-4 in difficult terrain or in a wooded environment. Production rates with the vehicular *MTADS* system are 7-10 hectares per day on areas with terrain typical of JPG. Vehicular production efficiencies are higher on larger sites because it is possible to use deployment strategies to more efficiently survey and analyze data. Daily, on-site, deployment costs are similar for the two systems. Mobilization costs are typically higher for the vehicular system because it requires leasing of a trailer truck and fuel and labor costs associated with transportation. In addition, in a commercial application, amortization or depreciation costs associated with the vehicular systems will be significantly higher for the vehicular system than for the man-portable adjuncts.

Without consideration of other complicating issues, deployment of the vehicular system to sites where it can be used is probably more efficient, if the sites are larger than 5 or 10 acres. For sites larger than 20 acres it would be difficult to rationalize use of the man-portable systems unless issues of availability arise, or if their use is required because of site logistics. Both the vehicular and the man-portable systems can be transported in the same trailer and could likely be simultaneously used, assuming the availability of the GPS equipment and the required labor to support simultaneous operations.

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Blackhawk GeoServices
Geophysical Data Processing
Procedures and QC Checks
MTADS DAS

Daily QC tests and data collection activities are recorded by the field crew on daily log sheets. The daily log sheets are delivered to the geophysical processor at the end of each field day along with the raw geophysical data. Processing of the geophysical data involves preprocessing, analysis, final target selection, and modeling of the targets. For data collected in real-time mode, the daily QC tests will be performed and processed as follows. However, field data files will be evaluated in real-time only (similar to 'mag and flag' operations) and will not be stored for future processing.

The preprocessing phase involves:

- Evaluation of static test;

  Before beginning data collection each day, the geophysical sensors are zeroed (EM only) and a static test file is acquired. This involves positioning the sensors over a known location and collecting data in static mode (without moving the coils) for two to three minutes. The drift of the sensors is monitored by the field crew to ensure the sensors are functioning within the specifications of the work plan. Additionally, the static data are evaluated by the processor and hard copy profile maps of reading versus time are generated during processing.

- Evaluation of standard tests (for EM sensors only);

  Standard tests are collected by the field crew before and after data collection each day. This is accomplished by positioning the EM sensors over a known location and recording data in static mode (without moving the sensors). These data are recorded by the field crew on the daily log sheet. The field crew then positions a standard board over the EM coils such that a metal object is centered over the coils. The new data readings are recorded on the daily log sheet. The standard readings for each morning and evening are kept on a spreadsheet that is maintained by the processor. The percent difference (from morning to evening) of the magnitude change (from background to standard) for each day is evaluated to ensure compliance with the work plan. Hard copy profile maps of reading versus time are generated during processing. The profiles show the EM data stream before and after the emplacement of the metal standard.

- Evaluation of lag correction and positional data check;

  A latency test is collected by the field crew before data collection each day. The purpose of this test is to monitor and adjust for time lag between the positional data stream and the data stream(s) generated by the geophysical sensors. This is accomplished by running the sensors over a known item (usually a metal spike) in two or more directions. The geophysical processor compares the responses from the multiple passes to determine if a time lag exists. If a time lag is present in the data, the processor adds a small time shift (starting with about 50ms) to the sensor data. The data are reprocessed with the time shift and re-evaluated. This process continues until all passes are in agreement. It is expected that the peak position for each pass will vary slightly depending on the frequency of the data acquisition. Once the lag is determined, the peak response for the latency test is recorded on a spreadsheet where it is

compared against the known location of the latency spike. The spreadsheet is monitored to ensure the positional data is within specifications according to the work plan. The positions are expected to vary slightly due to minor inaccuracies in driving the sensors over the latency spike each day. The average variance should not be more than one foot.

- Evaluation of field notes for cultural features;

  During data collection, the field crew may record the coordinates and/or draw a sketch of cultural features located in the survey area. If coordinates are known they are put in a database where they can be plotted on the color map of the geophysical data. During data analysis all data are evaluated for the presence of known cultural features. Anomalies that are expected to be associated with known cultural features may be excluded from the final target list.

- Evaluation of sensor data for time gaps and sensor failure;

  All geophysical sensor data are checked for time gaps and sensor failure. These checks are performed by the field crew during data collection by monitoring the computer display of the data streams. The checks are also performed during processing with an algorithm contained in the MTADS DAS preprocessor. The algorithm checks each geophysical sensor data stream independently for time gaps greater than the normal collection rate. Additionally, when multiple sensors are used in a single array, the algorithm compares the start and stop time for each sensor file and then compares the number of readings for each sensor. When the algorithm is complete a message is displayed for the processor and subsequently stored as a text file. If the checks are consistent with normal operating procedure (according to the work plan) no further action is needed. If the checks are not normal the data files are reviewed by the processor.

  A time gap in the geophysical data is usually caused by stopping and restarting data collection within a file and is part of the normal operating procedure. Sometimes, however, a gap in the data along a survey line may be produced. In this case, the coordinates for the starting and ending points of the gap are digitized and given to the field crew for reacquisition.

  A difference in the number of readings for each sensor may indicate that one or more of the sensors dropped out during the survey. This could be due to a loose connection or equipment failure. In this case data collection is stopped and the equipment is tested until the cause of the problem is determined. Equipment that is not functioning properly is replaced with back-up equipment and sent for repair. Data collection is repeated over all areas containing suspect data.

- Evaluation of positional data;

  The GPS data are checked for time gaps that are greater than the standard data collection rate. This is accomplished during processing with an algorithm that simply calculates the time difference between each GPS reading. When the algorithm is complete a message is displayed for the processor and subsequently stored as a text file.

  A time gap in the GPS data stream during data collection may be due to the loss of transmission from the GPS base station to the GPS rover. In most cases, the transmission interruption is observed by the field crew and data collection is halted. Troubleshooting is performed to determine the cause of the problem. It may be necessary for the field crew to

switch GPS frequencies or move the GPS base station to a location that is closer to the survey area. Data collection is repeated over areas suspected to have GPS data gaps.

In some cases, however, the GPS time gap may last a few seconds and may not be observed by the field crew. This will cause a gap in the processed geophysical data. In this case, the coordinates for the starting and ending points of the gap are digitized and given to the field crew for collection.

- Subtraction of magnetometer base station data;

  Before beginning a magnetometer survey, a magnetometer base station is set up in a geophysically quiet area. Base station data are collected during the magnetometer survey and downloaded once or twice daily. During processing, a diurnal correction is applied to the magnetometer data by subtracting the magnetometer base station data.

- Application of demedian filter;

  A demedian filter is applied during processing to remove sensor drift and level the data to a zero baseline. The filter length is controlled by the processor. The filter works by computing and subtracting the median value of all data points within +/- ½ of the filter length as input by the processor. This process is repeated over all data points. A 1000-point length for EM data and a 400-point length for mag data were standardized for the MTADS vehicle towed arrays based on field trials by NRL. The filter length for man-pulled or atv-pulled arrays may vary depending on the speed and frequency of data collection.

  Because the demedian filter eliminates features comparable to or longer than the filter length in both space and time, is also useful in removing long-wavelength geological features and diurnal effects (the latter supplements or can even replace a magnetometer base station). When significant changes in direction occur over distances comparable to or longer than this filter length, the demedian filter will effectively remove the heading error. The spatial, temporal, and debiasing features of the demedian filter make it an important part of MTADS preprocessing.

Following the preprocessing phase, the data analysis includes:

- Review of positional data quality;

  During processing the GPS data quality is reviewed. The DAS displays the GPS track with color-coded symbols that represent the level of accuracy for each GPS point (RTK, DGPS, etc.). Undesirable GPS points can be deleted or edited with a linear fill.

- Review of geophysical sensor data quality;

  Each geophysical sensor data stream is checked independently to ensure data quality. This is accomplished during the processing by looking at the profile of each data stream as well as the gridded and pixel data. Bad data (i.e. that which contains spikes, dropouts, etc.) are discarded and the data are recollected.

- Plotting the sensor data in gridded and pixel format;

The DAS grids the data with a default cell size of .2 meters. Both the gridded and pixel data are displayed for the processor.

- Applying filters to the gridded data (when necessary) to aid in target identification;

  Filters are sometimes applied during processing to enhance geophysical anomalies. The MTADS DAS has a variety of smoothing filters that can be applied to the grids. One or two passes of a narrow, lowpass boxcar filter (width = 3 grid cells) is commonly used to smooth the data. The gridded, filtered data are displayed adjacent to the gridded, unfiltered data for direct comparison by the geophysical processor.

- Application of analytic signal computation to total field magnetic data;

  As part of the normal MTADS processing, the analytic signal of the total field magnetic data is computed. The analytic signal is the absolute value of the total-field gradient in three dimensions (the vertical gradient can be computed from potential-field theory). The analytic signal computation yields positive-only anomalies that can be more easily picked and also provides better anomaly definition than the total field data. The analytic signal data are displayed adjacent to the total field data for direct comparison by the geophysical processor.

- Selecting targets utilizing a peak-picking algorithm;

  The geophysical processor uses a peak-picking algorithm as the initial step in target selection. Before beginning target selection, a threshold value is determined and agreed upon by the prime contractor. The initial threshold value for picking targets will be based on prove-out results conducted at the site. The prove-out should include the smallest item expected to be found at the site buried at the maximum depth of clearance with multiple orientations. The smallest anomaly peak will be used as the initial threshold value. This value may vary for each type of equipment used at the site.

- Review target selection;

  After running the peak-picking algorithm, the processor evaluates the targets that were selected. This is accomplished by panning through the data at various color scales while reviewing the target selection. All existing data displays are reviewed, including pixel and gridded data as well as any filtered or analytic signal images that may have been generated. At this time, the processor identifies additional targets that were not selected using the peak-picker. The field notes will be evaluated and targets determined to be related to known cultural features will be removed. Additionally, targets attributed to gridding and edge effects, are removed.

  A second target review will take place if Blackhawk receives dig results before completing the MTADS geophysical survey. The ground truth data will be compared with the DAS picks. An anomaly evaluation will be conducted and the percentage of "no-finds" will be computed. At this time the threshold value for picking future targets may be raised or lowered depending on ground truth results.

- Preliminary modeling of selected targets;

The raw geophysical data are modeled using the DAS modeler. The modeler at present considers magnetic, EM or joint mag/EM data. Targets are most commonly modeled as spheres. The modeled results provide an estimated size and depth for the selected targets. It should be noted that the depth estimate from EM data is not robust when the target is shallower than about one meter (this is a consequence of coil size).

- Generating an output of the final data in XYZ ASCII format;

  XYZ ASCII data files are generated from the pixel data. Headers can be added to each file to describe the data columns and provide specific information about data collection and processing. Alternatively, text files can be generated to describe each XYZ file.

- Evaluation of coverage (i.e., data gaps);

  The XYZ files are imported into an Oasis database where the final project maps are produced. The data files are gridded with a blanking distance such that data gaps greater than that specified in the work plan are evident. For example, if the work plan specifies that parallel survey lines can be no greater than four feet apart, the blanking distance is set at two during gridding. This ensures that grids will not be interpolated greater than two feet away from any data collection point.

  After data are gridded, they are checked for continuity between parallel survey lines and across neighboring grids. If a gap is found, the coordinates defining the boundaries of the gap are digitized and given to the field crew for data collection.

- Plotting a hardcopy map of the data with target locations superimposed;

  Oasis maps are updated daily during geophysical data collection. When target selection and modeling are complete, the target locations are superimposed on the color map of the geophysical data. A hard copy of the map is generated and delivered to the prime contractor for review.

- Producing a final target sheet;

  A final target sheet is produced which provides a unique number for each target along with the location, peak value, estimated size, and estimated depth. This is delivered to the prime contractor for review.

Notes:

Real-time operations are discussed in the RDD document dated 9/22/01, section 4.8, page 4-19. The MTADS MPA will be used as a hand-pulled system - very similar to "mag and flag" operations. Before being used at the site, a performance verification will be conducted at the test plot as described in the RDD. Static, standard, and positional tests will be performed daily to verify that the equipment is functioning properly. These tests will be evaluated by the geophysical processor as well.

The initial threshold value for picking targets will be based on prove-out results conducted at the site. The prove-out should include the smallest item expected to be found at the site buried at the maximum depth of clearance with multiple orientations. The smallest anomaly peak will be used

as the initial threshold value. This value may vary for each type of equipment used at the site. After applying the MTADS-DAS peak-picking algorithm to the data, the targets will be reviewed by the processor. The field notes will be evaluated and targets determined to be related to known cultural features will be removed. In addition, any anomalies not picked by the auto-picker will be added to the target list. Since the objective of this project is to remove all buried metal, it is likely that the picking threshold may be lowered from that which was determined by prove-out data.

Upon receiving dig results, all MTADS-DAS target picks will be reviewed. The ground truth data will be compared with the DAS picks. An anomaly evaluation will be conducted and the percentage of "no-finds" will be computed. At this time the threshold value for picking targets may be raised or lowered depending on ground truth results.

The MTADS EM modeler computes the response of a permeable sphere to a uniform field. The field is computed from the actual sizes, shapes, and positions of the MTADS coils. The targets are modeled as spheres because this is the only shape that has a complete analytical solution. In fact, we then take the spherical diameter and convert to a caliber assuming a 4.4:1 aspect ratio. We showed that this fit the caliber of test-pit data to within about 25% (1 standard deviation). This is with depth known; in practice, larger errors are possible because the 1-m MTADS coils are not very sensitive to depth within about 1 m (i.e., depths around 0.5 m). Formally we had a standard deviation of 0.25 m. An overestimate of depth will lead to an overestimate in size.

There are two other kinds of models out there. One is a complete numerical model, which we and two other groups are investigating. This is useful as an absolute standard against which to compare other models and to gain scientific insight into EM induction in UXO. But it is not practical to incorporate into production surveys.

The other approach is the "semi-empirical model" which is now widely used by AETC, Duke University, and others. It has been reported numerous times at the SERDP/ESTCP Symposium. We are currently working on SERDP and ESTCP projects that use it and a primitive version is indeed in our current version of MTADS. This models the target as two or three orthogonal dipoles (the sphere can be considered as three equal dipoles). This model fits data very well but doesn't have any way of predicting the response of real objects without matching to previous data.

The sphere model is simple but still useful: it is probably best at ranking targets by relative size perhaps without regard to absolute size. When a larger volume of field data becomes available, some discrimination can be achieved even with this simple model when its results are fed to the classifier. With more dig results available it should be possible to link the semi-empirical model and the classifier for even better discrimination.

APPENDIX L

RESUMES

HENRY M. MORRIS, P.E. — OE PROGRAM DIRECTOR

EDUCATION

MS, Engineering (Construction), University of Michigan, Ann Arbor, Michigan, 1970
BS, Civil Engineering, Tulane University, New Orleans, Louisiana, 1962

Professional Registrations

Professional Engineer, Alaska, 10233, 2000
Professional Engineer, Washington, 28588, 1992
Professional Engineer, Louisiana, 8491, 1962

Experience Summary

Mr. Morris has more than 35 years of project and program management experience, including 20 years of construction management encompassing field supervision, quality control, and multiple project/program management. Projects have ranged from a state-of-the-art hospital to expeditionary roads and bridges. During 12 years of managing environmental programs, Mr. Morris has been involved in underground storage tank (UST) management, upgrade, and removal; remedial actions involving diesel, gasoline, polychlorinated biphenyls, and asbestos; and environmental planning for spill response, water supply, construction project permitting, and facility closure. He has experience in construction and environmental services and remediation gained through his service as a Naval Officer and project manager.

Project Experience

Ward Cove Sediment Remediation, Alaska. Managed a $3.4-million contract for remediation of sediments in Ward Cove. The site requires experimental and controlled work practices to accommodate the very low strength of sediment to be capped, water depths for capping of up to 120 feet, and bottoms with slopes that range from gentle to very steep. Remedial actions for contaminated sediments were carried out by means of dredging approximately 22,000 cubic yards, and capping or mounding of 28 acres.

U.S. Army Corps of Engineers (USACE), St. Lawrence Island U.S. Air Force Base, Alaska. Managed a $3.2-million subcontract for the professional environmental services portion of a USACE contract to demolish and remove the former Air Force base at the northeast cape of St. Lawrence Island, Alaska.

U.S. Navy, RAC, Pacific Northwest and Alaska. Project manager, Senior Project Manager, and Program Manager for Navy remedial action contracts in the Pacific Northwest and Alaska. From October 1998 to May 2000, served as Program Manager for ACs I and II at EFA Northwest. RAC I was valued at $120 million, and RAC II was valued at $290 million. Project work included planning for dredging at PSNS, shoreline and upland restoration, and landfill cap at Jackson Park; operations and maintenance (O&M) of numerous remediation systems; dig and haul soil remediation projects; thermal treatment of soil at a remote site; and a freeze wall in the Arctic. Took over in a period of declining workload and personnel losses. Stabilized the workforce and raised morale. Increased workload from $10 million to $30 million per year. Improved the health and safety program, bringing reportable incident rate to zero. Implemented a safety incentive program.

- **U.S. Navy, RAC I, Washington.** Managed multiple RAC delivery orders including:
  - NAS Whidbey - managed soil remediation for three sites and drum disposal
  - Puget Sound Naval Shipyard - prepared plans for steam sparging and UST removals
  - Jackson Park - managed arsenic soil removal
  - Naval Air Station (NAS) Bangor - provided operations and maintenance services for two pump and treat systems
  - NAS Whidbey - managed public water connections and well closures
  - Jackson Park - provided drum and debris removal as a rapid response project
  - UXO work on Adak averaged about $7 million per year

- **U.S. Navy, RAC II, Washington and Alaska.** Managed multiple RAC delivery orders including:
  - Keyport - managed preparation of plans for demolition of plating plant
  - Puget Sound Naval Shipyard - managed steam sparging, phase II construction
  - NAS Bangor - managed continuation of O&M of two pump-and -reat systems
  - Keyport - managed demolition of plating plant.
  - Provided planning for remediation of petroleum-contaminated soils in the Pribilof Islands. Set up and ran immediate/rapid response program. Accomplished 12 projects over 2 years. Received Certificate of Appreciation from Commanding Officer EFA NW. Served as Senior Project Manager with oversight of up to 15 projects on 3 bases at any one time

Submarine Base Bangor, Washington. Improved quality and timeliness of construction and engineering support of base Operating Services Contractor serving Naval Submarine Base Bangor, Keyport, Indian Island, and Jackson Park. Managed a budget of $10 million per year, and supervised a multi-discipline staff of 52 engineers and support personnel designing and constructing a broad range of construction, repair, and environmental projects (average workload of over 200 projects). Environmental projects included establishing a UST management program for Subase Bangor, removing 20 petroleum USTs and 17 hazardous waste (plating, pesticides, and waste oil) tanks, including 5 site restorations ($450,000 construction cost). Developed and implemented a project control system that successfully controlled costs and schedules of in-house staff and subcontractors. Maintained a change order rate of less than 2 percent.

Madigan Army Medical Center, Tacoma, Washington. Managed the quality control program for construction of the $207-million Madigan Army Medical Center. Implemented a detailed program for the prime and 60 subcontractors that centered on conforming initial efforts to project plans and specifications, thus preventing rework and allowing superintendents and subcontractors to maintain schedule and cost controls.

Naval Undersea Museum, Keyport, Washington. Consultant providing oversight and assistance with design, construction, exhibits planning, and fundraising for a $6.6-million high-technology museum

U.S. Navy, Construction and Environmental Programs, Keyport, Washington. As an Officer in the U.S. Navy, served in several positions managing construction, public works, and environmental programs. At Keyport, Mr. Morris managed the $20-million per year Public Works program for a high-technology engineering and industrial complex utilizing 100 in-house and 200 contract man years annually. Developed long- and short-range facilities plans including $60 million in new ordnance facilities to support a new carrier port in the region. Strengthened environmental programs, including planning; and accomplished asbestos abatement at the boiler plant, converted the station from water wells to regional water system, started a program to identify all wastewater streams so that old drains could be rerouted to acceptable treatment, operated the industrial waste

treatment plant, and helped earn the Navy's top environmental award for management of forest, wildlife, and shoreline at Indian Island

U.S. Navy, Seattle Branch, Western Division, Naval Facilities Engineering Command. Director responsible for project management, facilities management, and environmental program management services to the Navy in the Pacific Northwest and Alaska. Managed site selection studies for a new naval base on Puget Sound. Mr. Morris developed base facility requirements, coordinated internal and contractor proposals, and effectively kept the project on track through liaison and public relations with local government, port authorities, and congressional representatives. Established a precise navigation system along the West Coast in one-half the forecast time and within budget. Developed a new water supply for Naval Facility, Pacific Beach, Washington., including obtaining water rights, public meetings, and hearings at state level.
Other projects included:

- Monitoring private water wells adjacent to Subase, Bangor, to determine presence of ordnance chemicals allegedly migrating from Navy property
- Assisting Naval Stations to identify, track, and dispose of industrial waste; supporting the closure/transfer plan for Navy Lab, Point Barrow, Alaska
- Preparing Spill Contingency Plans for Naval Base Seattle for both land and water spills of petroleum and hazardous materials
- Representing the Navy for environmental issues involved in Navy use of an off-shore bombing range that included Sea Lion Rock, which was in a wildlife preserve
- Developing environmental documentation supporting design and construction of the coal-fired steam plant at Puget Sound Naval Shipyard
- Developing applications and obtaining National Pollutant Discharge Elimination System permits for various Navy activities

U.S. Navy - 1980 - 1983

Prior assignments included 5 years of public works management and 9 years of construction management primarily with the U.S. Naval Construction Forces, including management of a program composed of 17 small military construction units throughout the United States.

Special Training

40-Hour OSHA Hazardous Waste Health and Safety Training, 1994 (with annual updates)

Professional Memberships

Society of American Military Engineers (SAME)

Employment History

06/2001-Present, Earth Tech
1994- 2001, Foster Wheeler Environmental Corporation, Program Manager
1988-1994, Johnson Controls World Services, Manager of Engineering and Construction Services
1986-1988, Blount Construction, Quality Control Manager
1985-1986, Naval Undersea Museum Foundation, Consultant
1964-1984, U.S. Navy, Civil Engineer Corps Officer

GREGORY J. PETERSON — OE TECHNICAL DIRECTOR

EDUCATION

Evaluated, 90 Credit Hours at various colleges and military experience by New York Regencies University External Degree Program, 1995
Senior Leadership Training in TQL, July 1993
Graduate, Naval Instructor Training, 4 Sep 1981
Navy Leadership/Management Education and Training, August 1981
Naval Instructor Training/Curriculum Development Course, July 1981
Graduate, Basic EOD School, 22 Jul 1977
Navy EOD Course Phase II, Land/Underwater Ordnance, July 1977
Explosive Ordnance Technologists, 1977, Charles County Community College, La Plata MD
Graduate, Second Class Dive School, Feb 1975
EOD Course Phase I, Chemical/Biological Weapons, July 1976
Graduate, Lake Crystal High School, Lake Crystal, MN 56055

HEALTH AND SAFETY TRAINING

All safety training has been on the job, Mr. Peterson served as Safety Officer at the command level for 8.5 years, managing Command Safety Programs.
Medic First Aid/CPR, June 1997
40-hour OSHA HAZWOPER course (29 CFR 1910.120), June 1997
8-hour OSHA HAZWOPER course, June 1998
8-hour OSHA HAZWOPER Supervisor course June 1998
CPR 1 First Aid current though June 1999

MILITARY EXPERIENCE

May 1996 - May 1997: Operations Officer/COMEODGRU ONE
April 1994 - April 1996: Readiness/Training Officer/COMEODGRU ONE
April 1992 - March 1994: Executive Officer/EODTEU ONE
June 1989 - April 1992: Operational/Readiness Officer/COMEODGRU TWO
November 1985 - June 1989: Officer in Charge/EODGRU TWO DET BERMUDA
November 1983 - October 1985: Curriculum Standards Dept Head/EODTEU ONE
October 1982 - November 1983: Officer in Charge/shipboard unit/EODMU ONE
September 1981 - June 1982: EOD instructor/NAVSCOLEOD
May 1979 - July 1981: Leading Petty Officer/EODGRU TWO DET GTMO BAY CUBA
July 1977 - May 1979: Reported to COMEODGRU TWO from NAVSCOLEOD

PROFESSIONAL SUMMARY

Mr. Peterson has over 22 years of experience in all areas of Explosive Ordnance Disposal (EOD)/ Unexploded Ordnance (UXO) clearance and demolition range operations at the field and management levels. He has approximately 2 years of civilian UXO experience in team supervision and program

management and 20 years of experience in military EOD programs. Mr. Peterson has 3 years of military field experience as a Senior EOD Technician directly supervising EOD teams and over 5 years of hands on range operations experience performing UXO operations. In addition, 8 of his 14 years as a Master EOD Technician have been spent directly supervising complex, multi-team EOD/UXO operations from priming the shot to managing complete projects. This experience includes all aspects of planning, logistics supervision, safety, training, and execution of operations with a perfect safety record.

- **OE Technical Director, A-E Environmental Services, Western Region, Corps of Engineers, Huntsville**. Project Manager for the Salton Sea Delivery Order and responsible for managing the OE program and providing OE technical and contractual support to project managers on delivery orders under this contract.

- **BioGenesis Pacific Inc. (BPI):** Mr. Peterson was hired to develop, organize, and manage a UXO capability for BPI for the purpose of conducting UXO operations in support of a USAF bombing range clearance operation. This contract was completed on time and with a 4.0 USAF approval rating, on a 4.0 scale. This project required the surface clearance of 2,600 acres of bombing range target area. During this clearance over 15,000 dud ordnance items were safely disposed of on site, and over 500 tons of ordnance/target scrap was gathered, inspected, certified safe to ship, and removed from the range. Mr. Peterson conducted this project with a team of 8 UXO personnel, 2 Equipment Operators, 16 Range Technicians, and 1 on site field Office Manager.

- **Human Factors Applications, Inc.** As a UXO Team Leader, conducted UXO remediation of several former ordnance impact areas for the U.S. Navy at NAS Miramar to clear the way for the construction of new facilities. This project included surface and subsurface remediation action.

- **Lockheed Martian Idaho Tech Co.** As UXO Team Leader, Mr. Peterson was responsible for the health and safety of a six-person team engaged in UXO remediation of several former explosive test sites located at the Idaho National Engineering laboratory. Using a systematic grid layout with visual and geophysical searches, live UXO rounds and several hundred pounds of bulk high explosives were safely removed.

- Ten years as enlisted and 15 years as a Naval Officer achieving the rank of Lieutenant Commander. Twenty years were been spent working in the EOD field in a wide variety of positions, including Team Member, Demolition Range Safety Supervisor, Diving Supervisor, Free Fall Jump Master and Instructor, EOD Instructor for U.S. and foreign students, Officer in Charge of Shipboard and Shore Detachments, Quality Control and Safety Officer for all east coast EOD assets, Executive Officer of an EOD Training Unit, and Quality Control and Operations Officer for all west coast EOD assets.

- Responsible for logistics and transportation of personnel, material, and equipment including explosives, fuels, vehicles, and boats throughout the U.S. and remote overseas locations to conduct EOD/UXO operations during fleet wide exercises and contractor job sites.

- Responsible for the planning, execution, and control of all Pacific Fleet EOD/UXO range activity including detection, clearance, disposal, and training for operations and fleet wide exercises.

- Directly managed/supervised large numbers of personnel and multiple subordinate commands assigned to both Atlantic and Pacific Fleet EOD forces.

- Mr. Peterson has had years of experience managing Command Safety Programs, including Explosive Safety and Quality Control Programs used to monitor EOD/UXO training and operations at the Command and Group levels.

- Five years of direct explosive allowance management, magazine management, and transportation and storage of UXO recovered during off base UXO responses.

- **Explosive Ordnance Disposal Group ONE.** As Assistant Chief inspector, Mr. Peterson was directly responsible for the administration of Pacific Fleet EOD Training/Readiness and Administrative Quality Control programs. As Officer in Charge of eight Quality Control Evaluators, he monitored the Readiness/Training and administrative effectiveness of eight subordinate commands and their detachments in the following areas: Command Safety Program, Hazardous Material Handling/Stowage Program, Ammunition/Explosives Handling and Certification Program, Personnel/Physical Security Programs. At the completion of each review, Mr. Peterson would draft a formal report to COMEODGRU ONE outlining the findings, and recommend a course of action to correct any deficiencies found. He also coordinated and facilitated all of the Commanders' staff level meetings and the Chief of Naval Operations-sponsored Executive Steering Committee meetings.

- **Explosive Ordnance Disposal Training and Evaluation ONE.** As the Executive Officer, Mr. Peterson was responsible for all command administrative functions, financial/materiel management of over $3.5m in funds equipment annually, and management of 52 personnel. He was Director of the commands' NAVOSH and Explosive Safety programs, passing all fleet level and navy wide inspections with a perfect score. Directly responsible for the Quality Control of all Pacific Fleet advanced training during his tour, including 1,484 diving operations, 74 demolition operations using live explosives, and 1,843 premeditated parachute jumps, with a perfect safety record, while providing advanced EOD training to 34 (seven man) EOD Detachments. Managed the implementation of a High Risk Safety Training Program, greatly improving the safety factor for students and instructors.

- **Explosive Ordnance Disposal Group TWO.** Mr. Peterson, as the Quality Control Advisor to the Commander, directed operations involving the location, neutralization, render safe, and exploitation of U.S. and foreign nuclear, chemical, conventional ordnance, demolition, dive, and parachute operations for the propose of evaluating the ability of Atlantic Fleet EOD units to safely and successfully conduct EOD/UXO range operations. He also developed special chemical weapons briefings for all Atlantic Fleet EOD personnel preparing for EOD/UXO operations during Desert Shield, and was responsible for developing numerous underwater ordnance clean up contingency plans for strategic harbors in support of Desert Storm. Served as EODGRU TWO Atlantic Fleet Safety Officer. During his tour, EODGRU TWO and all subordinate commands had perfect safety records and passed all NAVOSH inspections with zero discrepancies.

- **Explosive Ordnance Disposal Group TWO Detachment Bermuda.** Provided emergency and routine diving, demolition, and UXO render safe services to NATO military forces. As detachment Safety Officer, Mr. Peterson developed, implemented, and managed a NAVOSH program involving surface and underwater explosive operations, diving operations, air operations, small arms training, and ammunition and explosives use. Served as Detachment Dive and Demolition Supervisor. Conducted monthly demolition operations for the Bermuda Regiment and the U.S. Marine Corps Marine Barracks Company and provided the same units advanced demolition training.

- **World War II UXO Recover Project for the U.S. Trust Territories.** Mr. Peterson, as Officer in Charge, developed Standard Operating Procedures that enabled personnel to remove over 4 tons of Japanese WWII UXO from various Southern Pacific Islands. This was extremely dangerous as 80 percent of the ordnance was armed or was exuding picric acid. This project was completed under very remote conditions without incident. Served as Detachment Dive and Demolition Range Control Officer.

- **Makua Impact Area Target Renovation and Demolition Operations Project.** As Demolition Range Control Officer, Mr. Peterson was responsible for all operations on the range including transport of personnel, equipment, and explosives to and from the impact area, training of all personnel on the range, control of all demolition operations on the range, and responsible for over all safety of the operation. The project consisted of conducting UXO recovery and routine demolition operations monthly at Makua impact area to maintain impact target area sanitation and conducting command demolition operations for training purposes and for the disposal of retrograde ordnance.

- **Special Operations Project NORPAC Operations.** Mr. Peterson and his detachment were hand selected for this, at the time, highly classified project due to the detachment's outstanding reputation and their above average physical conditioning. This project required that Mr. Peterson's detachment be ready to launch its boat on 5 minutes notification 24 hours a day in extremely hazardous conditions in the Northern Pacific and Arctic Oceans. The detachment conducted several launches and recoveries in heavy seas without incident to personnel or equipment. They also recovered several free-floating objects from the ocean that were very beneficial to the United States' intelligence community.

- **Naval School Explosive Ordnance Disposal.** In this position, Mr. Peterson served as a Basic EOD Instructor responsible for classroom and practical instruction in aircraft hazards (cads, carts, injection seats), bombs and bomb fuses, (foreign and domestic), and missiles (foreign and domestic). Directed classes of 25 personnel in classroom instruction and field operations and was directly responsible for their safety while on the range using explosive render safe procedures during practical exercises.

- **Explosive Ordnance Disposal Group TWO Detachment, Guantanamo Bay, Cuba.** During this tour, Mr. Peterson was responsible for unit training, demolition, and range recovery operations. He was directly responsible for the destruction of over 39 tons of live anti-tank and anti-personnel mines during mine field maintenance operations, and 120 tons of UXO during maintenance and upkeep operations on 7 major ordnance impact areas. As demolition supervisor, he was responsible for the direction of all range operations at the detachment and supervision of three EOD personnel and up to ten minefield maintenance personnel from the Marine Corps at a given time. Mr. Peterson was also the detachment's Ammunition and Explosive Manager, responsible for the safe stowage, transportation, and security of all ammunition, explosives, and retrograde ordnance.

- **GTMO 2Omm Ammunition Range Remediation Project.** Mr. Peterson acted as the Range Control Officer and was responsible for remediation of the 2O-millimeter (mm) demolition range at GTMO. During the course of this project, over 50,000 rounds of live 2Omm ammunition were recovered from a 5-acre area and safely disposed of without incident.

- **GTMO Hazardous Material Neutralization Project.** Mr. Peterson acted as Safety Officer during the neutralization of 2,300 pounds of industrial chemicals. The operation was meticulously planned and conducted safely without incident.

- **GTMO Anti Tank Armed Fuze Removal Project.** As Range Safety Officer and Project Manager, Mr. Peterson developed a procedure that would allow the remote removal of 25 armed anti-tank fuzes via a modified tape and line procedure. The removal was at the request of an Explosive Safety Review Board. After removal, the fuzes were tested for deterioration because of prolonged field application in the mine fields at the Guantanamo Naval Base. This project was initiated after a fuze that was armed for many years detonated as it was turned to the safe position by Mine Field Maintenance Personnel. This project was completed without incident.

- **Dam Neck Lake Clearance Project.** EOD Team Leader and Project Explosive Manager, responsible for the safe stowage, transportation, and security of explosives, and retrograde ordnance. 10,000 ordnance items were safely removed, stored, and later properly destroyed.

Brian Weith, R.G. — PROJECT MANAGER

EDUCATION

B.S., Geology, Colorado State University, Fort Collins, 1985

TRAINING

EMS First Aid and CPR Training
NEPA Executive Overview Workshop
OSHA 8-Hour HAZWOPER Refresher Course
OSHA 40-Hour HAZWOPER Training Course
OSHA 8-Hour HAZWOPER Supervisor Training Course

PROFESSIONAL SUMMARY

Mr. Weith has over 12 years of experience as an environmental and geotechnical consultant. His environmental background includes the investigation and remediation of large DOD and commercial sites with a wide variety of soil and groundwater problems in accordance with the CERCLA process. Mr. Weith has investigated and remediated Formerly Used Defense Sites (FUDS) that have Unexploded Ordnance and/or Ordnance and Explosives (UXO/OE) environmental concerns from past use as either demolition sites and/or training ranges. His environmental background also includes the preparation of portions of NEPA and CEQA documents. As a geotechnical consultant he prepared preliminary soils reports, performed a number of fault investigations, evaluated sites for landslides, collected soil samples to determine engineering characteristics of site soils, performed on-site soils observation and testing during mass grading, and evaluated bedrock cut slopes for stability. He also collected and evaluated seismic data to determine rock hardness (rippability studies), subsidence, and faulting. His broad background of experience has allowed him to gain a working knowledge of a variety of subsurface investigations; report preparation; and federal, state, and local regulations. For the past 7 years he has worked as a project manager responsible for the development and management of budgets for large projects, client interaction, and coordination with federal and state agencies. The following is an overview of relevant project management experience.

Granite Management, OE/UXO RI/FS Investigation Tourtelot Cleanup Project, Benicia California.
As project manager, coordinates the RI/FS for both OE and non-ordnance remediation of the site, provides technical oversight and development of the project description for the Environmental Impact Report (EIR), and is the primary contact for the client on day-to-day management of the project. This high-visibility project is one of the first ordnance cleanup projects for which the California Department of Toxic Substances Control has been the lead agency. The project includes the investigation and characterization of several areas of concern which may have been impacted by past DOD activities, remediation of ordnance and explosives, soils engineering for grading of the property as a remedial step, and completion of EIR. This project has broken new ground in a variety of areas, has proceeded under a very accelerated schedule, required coordination among multiple offices, and preparation of a RI/FS report, Remedial Design Document, Remedial Action Plan, and EIR in parallel.

U.S. Army Corps of Engineers, OE/UXO EE/CA Former Benicia Arsenal, Benicia, California.
Managed this investigation to assess the risk of UXO to the public. This high-visibility project required an aggressive schedule to meet critical milestones for planned residential development on a portion of the property, including a public relations program that includes public meetings, development of fact sheets,

and production of informative videos regarding the investigation for viewing on public access channels. Developed the work plan and field investigation. Coordinated with local residents, businessmen, and local government agencies. The final EE/CA documented the findings of the field investigation, evaluated alternatives, and provided recommendations for risk management actions.

U.S. Army Corps of Engineers, OE/UXO EE/CA for Former Buckley Bombing Range, Aurora, Colorado. Managed the EE/CA for this large 60,000-acre site to assess the risk that UXO may present to the public. This high-visibility project had an aggressive schedule to meet critical milestones agreed upon between the state of Colorado and the USACE. The EE/CA was phased between three investigative zones that were based on public need with multiple tasks to be accomplished within each zone. The project faced many technical challenges that had to be addressed in meeting critical milestones.

Defense Distribution Depot, Ogden, Utah. Managed the investigation for several aboveground and underground storage tank sites for possible leaks/releases of hazardous materials into the surrounding environment. Prepared a work plan, sampling and analysis plan, and quality control plan, field investigation of the sites, and preparation of an engineering report presenting the results of the investigation.

Defense Distribution Depot, Oklahoma City, Oklahoma/Atchison Facility, Kansas. Managed the hazardous waste investigation of two large caves and outside support facilities used for the storage of various surplus items for the Department of Defense. Prepared a work plan, sampling and analysis plan, and quality control plan; conducted a field investigation of the sites; and prepared an engineering report presenting the results of the investigation. The challenge of accessing the caves with sampling equipment presented unique problems.

EE/CA for Former Baywood Park Training Area, Morro Bay, San Luis Obispo, California. Assisted in managing the investigation to assess the risk UXO may present to the public. The site is located in the ecologically sensitive sand dunes of Montana de Oro State Park. Assisted in preparing the work plan, managing field operations (to ensure sensitive habitat was not disturbed during the field investigation), tracking data, and producing the EE/CA.

Closure of Abandoned Wells, Former Norton AFB, California. Provided oversight for the proper closure of historic agricultural wells, base production wells, and homestead wells at the former Norton AFB. The project involved locating, abandoning, and documenting the closure of approximately 60 wells on the base. The process included overdrilling and/or drilling out the inside of the old abandoned wells. Once the field work was complete, detailed records of closure procedures were filed with the state and presented in a report

Environmental Assessment, Holloman High Speed Test Facility. Principal investigator in geologic and water resources for the preparation of an environmental assessment for the Holloman High Speed Test Facility at Holloman Air Force Base in New Mexico.

Geotechnical Soil Evaluation, Riverside, California. Conducted geotechnical soil evaluation of mass graded subdivision to determine the extent of underlying unconsolidated alluvial materials. Evaluated soil borings, soil sampling, down-hole logging of large diameter soil borings, and laboratory soil analyses to determine possible subsidence effects.

Preliminary Soils Investigations, Southern California. Conducted preliminary soils investigations of various commercial and residential properties throughout Southern California.

Phase I/II Environmental Site Investigations. Conducted site investigations for land acquisition of vacant land and existing structures for large Southern California banks and developers. Tasks included collection of potential asbestos building material, preparing samples for laboratory analysis, literature and records search, aerial photography review, and report writing.

Fault Investigations, California. Conducted fault investigations on the San Jacinto, San Andreas, Casa Loma, and Elsinore-Whittier fault zones. Investigations included extensive aerial photo evaluation, field observations, and profiling for determination of last activity along a particular fault splay.

Groundwater Surveys, Commercial Properties. Conducted various groundwater surveys for commercial properties, groundwater quality testing, and determination of groundwater basins and aquifer characteristics.

Geologic and Water Resources, Environmental Impact Statements (EISs), and Environmental Baseline Surveys (EBS). Principal investigator for geologic and water resources for base closure EISs at March AFB, California; Gentile Air Force Station, Ohio; and Newark AFB, Ohio. Principal investigator for geologic and water resources for a baseline EBS of Eglin AFB, Florida, which included extensive research on geologic hazards, mineral resources, water quality, and water quantity for the base and the surrounding environment.

Groundwater Well Installation and Destruction. Served as field supervisor for the installation of large extraction and production wells and the destruction of a large number of groundwater monitoring wells and abandoned agricultural wells.

EMPLOYMENT HISTORY

1994-present	Earth Tech, Project Geologist II
1989-1994	GeoSoils, Inc., Staff Geologist

CITIZENSHIP

United States

APPENDIX M

REFERENCES

APPENDIX M
REFERENCES

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Earth Tech, 2000. Final Engineering Evaluation/Cost Analysis, Former Benicia Arsenal, Benicia, California, prepared for U.S. Army Corps of Engineers, Huntsville Division, Ordnance and Explosive Design Center, March.

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APPENDIX N

T-10 TRANSPORTABLE
DONOVAN BLAST CHAMBER
STANDARD OPERATING PROCEDURE

DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD
2461 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22331-0600

DDESB-KO

31 JAN 2000

MEMORANDUM FOR DIRECTOR, US ARMY TECHNICAL CENTER FOR EXPLOSIVES SAFETY (ATTENTION: SIOAC-ES)

SUBJECT: Explosives Safety Submission for the T-10 Transportable Donovan Blast Chamber

Reference: Memorandum for DDESB-KO from Defense Ammunition Center, 6 January 2000, Same Subject

The subject safety submission forwarded by the reference has been reviewed with respect to explosives safety criteria. The safety submission is for a portable, detonation chamber (the T-10 Transportable Donovan Blast Chamber) that is designed to fully contain blast overpressure and debris from intentional detonations. Based on the information furnished, the subject safety submission is approved as follows:

(a) This approval only addresses requirements for intentional detonations inside the T-10 Chamber. It does not address the likely more stringent quantity distance (QD) requirements for operations leading up to these intentional detonations. The siting for these related operations must be separately approved.

(b) This approval is for activities similar to those necessary for site remediation and/or evaluations of the capabilities of the T-10 Chamber. Operation of the T-10 Chamber will be consistent with the procedures outlined in Enclosure 1 of the reference.

(c) Any future modification that might affect the blast resistant capability of the T-10 Transportable Donovan Blast Chamber must be approved by Department of Defense Explosives Safety Board (DDESB).

(d) Intentional detonation that does not produce primary fragments: The net explosives weight (NEW) limit for this configuration is 13 pounds (TNT-equivalent) or 10 pounds (HMX-equivalent).

(e) Intentional detonation that produces primary fragments: Fragment producing munitions with diameters up to and including 81 mm may be intentionally detonated. Munitions with diameters exceeding 81 mm may only be detonated IAW the applicable procedures of Enclosure 1 to the reference.

(f) When the T-10 Chamber is closed and ready for an intentional, internal detonation, all DoD 6055.9-STD criteria are satisfied for personnel located more than 18 feet from the T-10 Chamber. During an intentional detonation, hearing protection is required for

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personnel within 18 feet of the T-10 Chamber. Personnel who are within 18 feet of the T-10 chamber during an intentional detonation must have ear protection to limit sound levels they experience to 140 db.

(g) The T-10 chamber does not mitigate hazards from chemical, biological, or WP munitions.

Retain a copy of the complete site plan package and this letter of approval as a permanent record at locations where the T-10 Chamber is used.

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EXPLOSIVE SAFETY SUBMISSION

FOR

A COMMERCIALLY DEVELOPED

PORTABLE CONTAINED DETONATION CHAMBER

FOR UNEXPLODED ORDNANCE

T-10 Transportable

Donovan Blast Chamber

02 February 2000

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1.0 EXECUTIVE SUMMARY

This Explosive Safety Submission (ESS) has been written for a commercially developed transportable contained detonation chamber (The T-10 Donovan Transportable Blast Chamber) for use in destroying Unexploded Ordnance (UXO) at the request of the U.S. Army Engineering and Support Center, Huntsville, Alabama, U. S. Army Corps of Engineers.

DeMil International's intent is to provide our government clients through, direct sale or lease the use of the Donovan Blast Chamber technology. Training and/or expert personnel will be provided to our government clients. It is also our intent to limit our non-government clients to lease/rent agreements only.

The above limitation (i.e., operated by Demil International or Demil International-trained DoD or DoD contractor employees) does not preclude qualified DOD organizations from independently operating, providing training in the operation of, or conducting tests of the T-10. Such testing may be done, for example, to expand the capability of the chamber. Examples of qualified Army organizations include, but are not limited to the U.S. Army Defense Ammunition Center and the Huntsville Engineering and Support Center. The Donovan T-10 system provides an alternative to either open detonation or transportation of recovered ordnance to a remote site for disposal. The system can be used to intentionally detonate small ordnance items, generally ranging in size up to and including the 81-mm HE mortar rounds on a repetitive basis. The system can be used where open detonation is not an acceptable method due to the proximity of persons or property, or where transportation of ordnance to remote sites is impractical or not economically feasible.

The "Donovan Blast Chamber" is a box within a box fabricated from high quality steel with a vent system to control the discharge of the overpressures and detonation gases. The voids between the steel walls of the boxes are filled with silica sand to dampen and absorb the detonation shock. The interior is lined with 12" x 12" x 1/2" armor plates to mitigate shrapnel abrasion and damage to the T-10 interior walls. The interior floor is covered with a layer of pea gravel that acts as a shock absorber to reduce and control shock waves. Water is suspended in plastic bags inside the chamber to reduce temperatures. Overpressures and detonation gases are vented to an expansion chamber and finally to a baghouse system to filter out particulates associated with the detonation gases.

The T-10 system captures and controls all of the shockwave, overpressures and the detonation gases and discharges these gases in a controlled fashion through an expansion chamber and an Air Pollution Control Unit (APCU). No measurable pressure wave leaves the container except a small unmeasureable amount through the APCU exhaust outlet. Noise levels of a 10 lb HMX (13 lbs. TNT) detonation in the T-10 system are approximately 130 dB at a distance of 30 feet (see Vibronics Air Overpressure Testing of Ordnance Disposal Report in Appendix C). An OSHA Noise Exposure table is supplied in Appendix D (OSHA 1910.95). The T-10 system can be used for a virtually unlimited number of detonations at highly productive throughput rates.

Safety, pollution control, simplicity of use, simplicity of maintenance and the ability to detonate within the chamber repeatedly are the real advantages of the technology. A copy of the patent (Patent Number 5,613,453) is included in the Appendix B. This patent depicts a similar but larger chamber already in use; however, the patent depicts (and protects) the blast suppression technology that is common to all Donovan blast chambers. Photographs of the T-10 are provided in Appendix A. Because of the proprietary nature of the engineering drawings for the T-10, the Department of Defense Explosives Safety Board (DDESB) and Army review agencies agreed that they need not be a part of this safety submission. However, parties in the submission review chain have reviewed copies of engineering drawings.

Donovan Demolition Inc. (DDI), DeMil's technology affiliate, is the world leader in the contained detonation industry for use in explosive depth hardening of manganese steel railroad crossing castings. DDI hardens greater than 95% of domestic manganese steel railroad crossing castings and

is the largest commercial user of plastic bonded explosive sheet in the USA. The DDI prototype Blast Chamber has been in use for over ten years and has withstood 600,000 detonations without a failure or serious maintenance problems.

1.1 Nomenclature

The Donovan Blast Chambers are identified by the rated contained detonation capacity. Initially, the nomenclature was established based on equivalent TNT. The two Milan Army Ammunition Plant (MAAP) stationary systems were called D-130s (capable of withstanding detonations of equivalent to 130 lbs. of TNT). DeMil International is changing this designation to withstanding detonations equivalent to 100 lbs. of HMX. The stationary D-130s are now indicated as D-100s. The transportable systems are indicated by a 'T' followed by the rated capacity of the blast chamber in lbs. of HMX. Example: the T-10 is a transportable blast chamber system that is rated to withstand detonations of an equivalent 10 lbs. of HMX (13 lbs. TNT).

1.2 Scalability

The size of the chamber and its component sizes vary according to the Net Explosive Weight (NEW) desired. "Donovan Blast Chambers" currently in operation range from 3 lbs. to 100 lbs. equivalent HMX (3.9 lbs. to 130 lbs. TNT) NEW. The size is a function of the Propellant Explosive Pyrotechnic weight (PEP WT) and is not a linear function. The methods and calculations for determining the dimensions and Engineering Drawings of a "Donovan Blast Chamber" are proprietary information and are not available for this document. Interested parties can request this information from DeMil International, Mr. John Donovan (Inventor and Patent holder) and this information can be made available on a need to know basis.

1.3 Environmental Permitting and RCRA

This ESS is written assuming that this transportable Contained Detonation Chamber will be used in an emergency response situation and will not be subject to regulation under Subpart C of RCRA. Therefore, it is assumed that UXO will not be classified a hazardous waste and the demolition of the UXO is not a permitable hazardous waste treatment activity. If the T-10 is used in more of a production application for the extended on-site demolition of UXO or any other explosive, these activities may be subject to permitting under RCRA. (See the Military Munitions Rule, 40 CFR Parts 260, 261, 262, 263, 264, 265, 266 and 270.) If the T-10 is used in normal USACE range clearance applications the UXO is not subject to Subpart C of RCRA.

Warning

- **Total explosive weight (donor charge and NEW of the projectile) must not exceed 10 lbs. HMX (the equivalent of 13 lbs. TNT).**
- **Limit explosive items to a fragment hazard of less than or equal to an 81-mm HE mortar. Rounds larger in caliber than 81 mm mortar may or may not present a fragment hazard less than or equal to an 81mm HE mortar. Do not destroy rounds larger in caliber than 81mm until the round's fragment hazard has been determined. The U.S. Army Engineering and Support Center, Huntsville will, on a reimbursable basis, determine the fragment hazard of such rounds.**
- **Explosive items must be wrapped in sheet explosive.**
- **Detonation of any munitions without an appropriate countering donor charge and an appropriate quantity of water in the chamber can result in structural damage and increased shrapnel hazard.**
- **Only conventional high-explosive ordnance items can be destroyed; chemical, biological, or white phosphorous munitions should not be detonated in the T-10 system.**

2.0 INTRODUCTION

DeMil International has designed, and fabricated a fully operational transportable contained detonation chamber system (T-10) capable of repeated detonations of up to 10 pounds HMX (equivalent of 13 lbs. TNT) Net Energetic Weight (NEW). The system can be used to intentionally detonate small ordnance items, generally ranging in size up to and including the 81-mm HE mortar rounds with a donor charge on a repetitive basis. The T-10 system was designed to provide the safe containment of the shrapnel hazards and the controlled discharge of the detonation overpressures and gases without polluting the environment. The heart of the system is the patented "Donovan Blast Chamber" technology.

This document is intended to provide sufficient information to permit the approval of the "Donovan Blast Chamber" for use in destroying unexploded ordnance (UXO) at OE sites. A description of the T-10 system, including the functionality of each component, is provided in Section 3.2. The design and testing of the T-10 system is summarized in Sections 3.3, 3.4 and 3.5. Section 4 discusses evaluating ordnance to be demolished. Section 5 discusses inspection, maintenance and repair. Section 6 presents Operations Log Book example sheets. Section 7 discusses recognition of potential chamber failure.

2.1 Safety

The Donovan Blast Chamber was designed to minimize and/or eliminate the three hazards associated with a conventional explosive event. These are overpressure, thermal, and fragment hazards. The intent of the original prototype chamber that was designed and built over ten years ago for Donovan Demolition, Inc., Danvers, IL was to reduce the noise of detonation, allow for 24-hour operations and safely reduce QD standoff distances to zero. The intent with all Donovan Blast Chambers is to achieve all of these goals.

2.1.a. Overpressure and Shock Wave Mitigation

The T-10 Donovan Blast Chamber is a vented contained detonation chamber (CDC) system. As such, it does not physically contain all of the detonation gases. It vents the detonation gases in a controlled discharge through venting manifold to an expansion chamber and to an Air Pollution Control Unit (APCU). The T-10 system minimizes the overpressure hazard and virtually eliminates the Shock Wave hazard.

2.1.b. Temperature Mitigation

The Donovan Blast Chamber is unique in that it uses water to reduce peak pressures and temperatures. The fireball is significantly quenched with water. This reduces residual temperature and allows for quick turnarounds and repetitive shots in the T-10. The T-10 system has a temperature recording system that automatically detects and records peak detonation temperatures within the Expansion Tank and Air Pollution Control Unit. This data can be used to establish statistical control limits (operating parameters) based on the NEW.

2.1.c. Shrapnel Hazard Mitigation

The T-10 CDC interior (ceiling, walls, floor, access door and vent door) is covered with ½ - inch thick, 11.5" x 11.5" Armor Plates (AR-500 Steel). This armor plating allows greater engineered capacity for the T-10 to withstand shrapnel hazard on a long-term basis. This also allows for the removal and replacement of damaged and worn armor plating. The net result is a safer more robust T-10 design. The operator will monitor the erosion of the armor plate visually and any excessive erosion should be communicated to DeMil International.

2.1.d. QD Stand-off Distances

If the Donovan Blast Chamber technology is used according to design criteria and maintained according to maintenance procedures and munitions preparation and handling follows established standard operating procedures, when the access door is closed and secured on the chamber, the QD stand-off distance is zero (0) feet. Other QD standoff distances for other explosive devices within the operations area are to be observed. All Application of safety directives and procedures are site specific and organization specific and should be determined on a site-by-site and project-by-project basis.

The emplacement of this chamber at an operational location to conduct non-emergency responses (for example, to support a range cleanup project) constitutes an explosives operating location requiring DDESB quantity-distance (Q-D) site plan approval. General Q-D siting criteria are as follows: The chamber shall be sited applying applicable explosives safety distances based on consideration of (1) the largest quantity of UXO and demo charges planned to be staged or prepared at the chamber operating location, (2) location of the preparation station [where the rounds are wrapped before loading into the chamber], (3) the minimum separation distance for the most probable munition (MPM), and (4) what else is around the chamber location [storage areas, clearance areas, non-related activities (houses, admin areas, roads, etc.)]. The chamber operation poses only an unintentional detonation risk (wrapping rounds, placing the shot into the chamber, etc), while sites (such as ammunition storage areas or open detonation sites) around the chamber may pose risk from unintentional and intentional detonations.

2.2 Safety features

- The technology has been in use, commercially, for over 10 years and withstood over 600,000 detonations without a single failure.
- The system is keyed for a firing set system.
- The operator keeps the key to this firing set on his person at all times.
- There is an end line disconnect located at the end of the detonation transmission line.
- Robustness of design and scalability of the system make over-engineering for safety an economical option.
- The T-10 system provides a safe way to increase demilitarization throughput.
- The T-10 allows the safe detonation of highly hazardous materials, energetics, and assembled weapons near populated and developed areas that have typically grown up around older military ranges and ammunitions plants.
- The T-10 eliminates fragmentation hazards associated with these detonations.
- The T-10 eliminates detonation shock wave to acceptable industrial standards.
- The production T-10 is instrumented with a Peak Pressure and Temperature Monitoring System to insure the integrity and safety of the detonation chamber system on a continuous basis.

3.0 DEVELOPMENT OF THE T-10 FOR DESTROYING UXO

This section provides information about the T-10 blast chamber system and the design and testing performed in its development. According the USACE, ninety percent or more of the UXO is 81-mm mortar or smaller. With this information in mind, DeMil International designed and developed the T-10 to address this +90%. The purpose, structure and configuration of the T-10 systems are described below.

3.1 Chamber Purpose

The T-10 system is intended to provide an alternative to open detonation, temporary storage, and/or transporting recovered OE items to a remote site for detonation. If the item can be moved, then the T-10 system offers the alternative of detonating the item at a selected location on the remediation

site, close to the location of the OE, and on the same day. The T-10 system provides complete control of the safety hazards involved in such demilitarization. For munitions meeting the charge weight and fragmentation limits, the T-10 system captures and controls all shock overpressures and primary fragments from the munitions.

The explosive charge limit for the T-10 system is equivalent 10 pounds HMX (13 lbs. TNT), including all OE items to be destroyed and any initiating (donor) charge. Only conventional high-explosive ordnance items can be destroyed; chemical, biological, or white phosphorous munitions should not be detonated in the T-10 system. Specific procedures for determining whether an OE item can be detonated in the T-10 system are discussed in Section 5.

3.2 Description and Function of Components

This section provides a complete description of the T-10 system. The function of each component is described, to illustrate the role each segment plays in defeating overpressure and fragment hazard. Engineering drawings are not provided for this document. However, the engineering drawings are available by requesting in writing, to DeMil International. These Drawings are considered Company Proprietary Information.

3.2.a. Detonation Chamber

Consists of two-walled construction fabricated of standard mild flexible steel (A-36). Overall exterior dimensions are 6' 7" wide, 6' 7 ½" long, and 7' 11" high. Chamber weight with silica sand is 40,050 pounds. The interior of the chamber is lined with hardened abrasion resistant armor plate (11.5" x 11.5" x 1/2" steel armor plates, AR-500).

3.2.b. Silica Sand

Voids between walls are filled with dry silica sand that function as a shock absorber. The silica sand is added to the chamber walls during fabrication in a very dry condition and should remain dry. Ideally, the silica sand would have 0% moisture with 0% humidity. Under normal fabrication conditions atmospheric humidity can range from 30% to 100%. Every effort is made to ensure that the silica sand is as dry as is practical. The silica sand should have no visible signs of moisture. This is usually indicated by its ability to flow freely. This enables the silica sand to flow into all the voids in the chamber walls, bottom and top. Failure to fill the voids with silica sand can lead to structural failure in the chamber. Care should be taken to keep moisture from entering the wall voids. Damp or wet silica sand does not absorb shock waves well and could cause damage to the blast chamber. Sand levels should be checked, particularly with a new chamber, and refilled when needed. Some settling of the sand is expected in a new blast chamber system. (See Section 5 Maintenance and Inspection.)

3.2.c. Detonation System

Exploding Bridge Wire detonators are used exclusively with all Donovan Blast Chambers. These contain no primary explosives and are a go/no go detonator (i.e. No cook-off time, higher safety factor). The FS-61B Exploding Bridgewire Firing Unit, developed by Reynolds Industries Systems, Incorporated, (RISI) is a 110 V AC powered system used to initiate Exploding Bridgewire Detonators (EBW). The maximum stand off distance that you can still use this detonation system is one hundred (100) feet.

3.2.d. Pea Gravel

A minimum of 6 inches (12.5 cubic feet, 1100 pounds) of pea gravel is maintained on the chamber floor. The pea gravel is washed and screened to 3/8" diameter. This gravel acts as a shock absorber and should be checked periodically (see maintenance section). During a detonation the pea gravel is buffeted by the shock waves and overpressures and this causes dust particles to form, which are

discharged with the detonation gases. These dust particles provide nuclei for detonation by-products to adhere to during cooling which in turn are more easily trapped in the APCU. The pea gravel eventually has to be replaced (see maintenance section). The pea gravel can be contaminated with shrapnel, heavy metals, energetics and detonation by-products and should be tested to determine its waste characterization (hazardous or nonhazardous). The type and number of munitions detonated can determine waste characterization. If determined to be hazardous, disposal should meet all federal, state and local solid waste disposal environmental regulations.

3.2.e. Water

Typically a 1.5 to 1.0 ratio of water to total energetic is used, this is subject to change with type of energetic, type of munitions and other unique conditions. Zip lock plastic bags or balloons are filled with the appropriate amount of water and placed strategically within the detonation chamber (See photograph Appendix A). Note: Water quenches the detonation fireball and significantly reduces peak temperatures. Failure to use the appropriate amount of water significantly reduces the chamber structural life due to excess temperatures in the steel walls, which can lead to premature metal fatigue and possible failure.

3.2.f. Expansion Chamber

Single walled construction fabricated entirely of steel. On the T-10 transportable systems, the expansion tank volume is sized at a greater than 1 to 1 ratio to the blast chamber volume. The expansion tank is a rectangular vessel that is reinforced with either I beams and/or channel steel to provide rigid strength to the vessel. The interior dimensions are 8' x 8' x 8'. The weight is 5,300 pounds. The expansion chamber provides a controlled volume of space at atmospheric pressure to mitigate overpressures and heat from detonation gases. The expansion chamber provides more equalized airflow and reduces stress on the APCU. A 10-lb HMX (13 lbs. TNT) detonation produces three (3) pounds per square inch of pressure at the discharge of the expansion chamber. The 2.7-lbs. detonation of the 81-mm surrogate Mortar round produces about one (1) pounds per square inch of pressure at the discharge of the expansion chamber.

3.2.g. Air Pollution Control Unit (APCU)

The APCU is designed by Torit Industries specifically for the Donovan Blast Chamber. Dimensions are 10'2" high, 8'6" wide, and 7' long weighing approximately 3,000 pounds. This APCU can withstand pressures of up to twenty (20) pounds per square inch. The APCU fan is turned on just prior to detonation. The particulates from the detonation are cleared from the filter by automatic reverse airflow. Electrical requirements are 480 volts (3 phase) at 20 amps. This is a baghouse air/gas filtration system designed to capture particulates and detonation by-products. The particulates are deposited into a container that can be emptied periodically. The particulates can be contaminated with heavy metals, energetics and detonation by-products and should be tested to determine its waste characterization (hazardous or nonhazardous). If determined to be hazardous, disposal should meet all federal, state and local solid waste disposal environmental regulations. (See Appendix D for more information)

3.2.h. Air Compressor

Compressed air is introduced into the detonation chamber immediately after detonation. The APCU fan is on during detonation also. Once the chamber access door is closed and prior to detonation no air is moving through the system. During detonation the overpressure is vented to the expansion chamber and finally to the APCU for filtering and discharge. The compressed air provides replacement air in the chamber and helps remove the particulates and other associated detonation by-products out of the chamber and expansion chamber to be captured by the APCU's filters. This quick air replacement aids in cooling the chamber. The T-10 Blast Chamber requires compressed air at a rate of 100 cubic feet per minute at pressures of about 90-100 pounds per square inch.

3.3 Summary of Design

This section presents the relevant details of the preliminary and final design phase for the development of the transportable contained detonation chamber. Preliminary design was based on the prototype stationary Donovan Blast Chamber located at Donovan Demolition Inc. in Danvers, IL and the two D-100 Stationary Contained Detonation Chambers located at Milan Army Ammunition Plant (MAAP) Milan, TN. The T-10 is a scaled down version of the D-100 design. Exceptions are that the T-10 does not have or need a hydraulic system to operate the access door. The T-10 does not have a vent door that the stationary systems have. The APCU pulls air through the chamber system to draw particulates into the filtering system and out of the detonation chamber.

3.4 Monitoring System

The production T-10 is equipped with monitoring systems to log temperature and pressure during operation via pressure and heat sensors located in the expansion chamber and the APCU. This information can be used to safeguard the system from being overcharged and also allow technicians to retrieve information regarding temperature and pressure readings at specific intervals.

3.5 Design Criteria

The specific design criteria for the T-10 contained detonation chamber were as follows:

a) The total design charge weight is to be equivalent 10 pounds HMX (13 lbs. TNT) and capable of repeated destruction of up to two (2) 81-mm HE mortar rounds at a time.
b) Capability of repetitive shots.
c) The chamber would be mountable on a trailer for easy transportation.
d) The ability to contain and mitigate the primary shrapnel hazard of the target munitions. (Target munitions for shrapnel hazard are the 81-mm HE mortar round)
e) The ability to control and mitigate all shock wave and overpressure hazards.

3.6 Chamber Design

These are representative drawings of how the chamber is configured and the important components of the chamber technology. Generic drawings on the D-100 (D-130) are included in Appendix B in the Patent (No. 5,613,453). The Air Pollution Control Unit is not included in the diagram because it is commercially available air filtration system (Torit TD 573 Dust Collector).

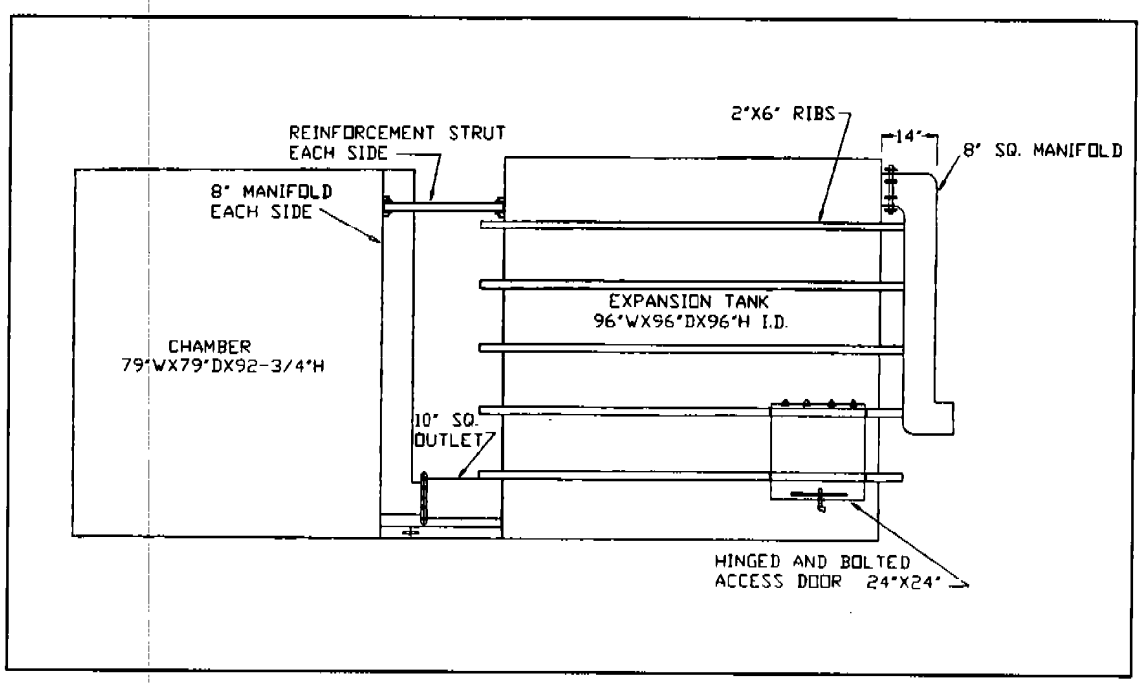

Figure 1. Line Diagram of the T-10 Donovan Blast Chamber (APCU not shown)

3.7 Summary of Testing

Vibronics (Evansville, IN) conducted air overpressure testing on the T-10 blast chamber on July 8, 1999. One open air shot of 5 lbs. HMX (6.5 lbs. TNT equivalent) was used as a baseline shot, one chamber shot of 10 lbs. HMX (13 lbs. TNT equivalent) (bulk) and three (3) shots of a surrogate 81-mm mortar rounds were monitored. A summary of the results are presented below, the complete report is included in Appendix C.

Summary of Noise data for the T-10 Stationary Contained Detonation Chamber:

Test # 1 - Open Air (Baseline Shot)

Comments	NEW (HMX)	Distance (feet)	A.O.P.* (dB)
Open Air	5 lbs.	800	>142**
Open Air	5 lbs.	1200	>142**
Open Air	5 lbs.	1270	>142**
Open Air	5 lbs.	1400	>142**

* Sound pressure level reported in decibels-peak, linear, fast response (impulse).
** Sound pressure level exceeded range setting on recording instrument.

Test # 2 - First Blast Chamber Shot (Bulk Explosive)

Comments	NEW (HMX)	Distance (feet)	A.O.P.* (dB)
Chamber	10 lbs.	30	128
Chamber	10 lbs.	100	119
Chamber	10 lbs.	500	106**

* Sound pressure level reported in decibels-peak, linear, fast response (impulse).
** Sound pressure level below trigger level or threshold of instrument.

Note: Both 100-foot stations recorded 119 dB (54 psi) even though they were in different directions.

Test # 3 - Second Blast Chamber Shot (1- Simulated 81-mm HE Mortar Round)

Comments	NEW (HMX)	Distance (feet)	A.O.P.* (dB)
Chamber	3 lbs.	30	118
Chamber	3 lbs.	100	101
Chamber	3 lbs.	500	95**

* Sound pressure level reported in decibels-peak, linear, fast response (impulse).
** Detonation masked in background noise.

Note: Detonation pressure as recorded 100 feet away – 98 dB (4.8 psi) on an azimuth 150° from array line.

Test # 4 - Third Blast Chamber Shot (1-Simulated 81-mm HE Mortar Round)

Comments	NEW (HMX)	Distance (feet)	A.O.P.* (dB)
Chamber	2.7 lbs.	30	117
Chamber	2.7 lbs.	100	100
Chamber	2.7 lbs.	500	90-95**

* Sound pressure level reported in decibels-peak, linear, fast response (impulse).
** Detonation masked in background noise.

Note: Detonation pressure as recorded 100 feet away – 96 dB (3.8 psi) on an azimuth 150° from array line.

Test # 5 - Fourth Blast Chamber Shot (1-Simulated 81-mm HE Mortar Round)

Comments	NEW (HMX)	Distance (feet)	A.O.P.* (dB)
Chamber	2.7 lbs.	30	117
Chamber	2.7 lbs.	100	98
Chamber	2.7 lbs.	500	97.1**

* Sound pressure level reported in decibels-peak, linear, fast response (impulse).
** Detonation masked in background noise.

Note: Detonation pressure as recorded 100 feet away – 96 dB (3.8 psi) on an azimuth 150° from array line.

OSHA requires operators to wear hearing protection for impulse noise exceeding 140 db. 140 db exceeds the DOD 6055.9 STD requirement of 148 db (K328). Therefore, 140 db will be used to determine the distance at which hearing protection is required. Using the data above for the largest shot (10 lbs HMX, or 13 lbs TNT, the chamber NEW limit), the 140 db distance is computed to be 17.4 ft (round up to 18 ft).

Therefore, operators within 18 ft of the chamber must wear hearing protection during shots.

The 17.4 ft distance was computed as follows:

The data above states that the largest shot produced the following measurement: 128 db at 30 feet.

128 db is .00723 psi. This equates to a K factor of K1000 (actual K factor is greater but beyond the upper limit of the Kingery Curve. Using K1000 is therefore safety conservative).

Using formula D = KW**1/3, if D= 30 ft and K = 1000, then W**1/3 = .03 lb. .03 lb is the cube root of the effective explosive weight had the shot been in the open and yielded 128 db at 30 ft.

140 db is .029 psi. This equates to a K factor of K 580 on the Kingery curve.

Using formula D = KW**1/3, if K = 580 and W**1/3 = .03, then D = 17.4 ft.

4.0 EVALUATING ORDNANCE TO BE DEMOLISHED

Only conventional high explosive munitions up to and including the 81-mm HE mortar round plus donor charge can be demolished in the T-10 blast chamber. Rounds larger than 81mm can be detonated in the chamber provided their fragment hazard is no greater than an 81mm and provided that the chamber shot NEW is no greater than 13 lbs. TNT equivalence. The U.S. Army Engineering Support Center Huntsville (USAESCH) will be contacted to analyze rounds larger than 81mm to determine their fragment hazard. Chemical/biological munitions should not be detonated in the chamber system. White phosphorus devices should not be demolished in this chamber (these procedures have yet to be developed and DDESB approved).

The Army Ammunition Data Sheets, Artillery Ammunition, Guns, Howitzers, Recoilless Rifles, Grenade Launchers, and Artillery Fuzes (TM 43-0001-28) is the best source of information on munitions/UXO if it is in good enough shape to be identified. These data sheets provide the necessary information on most if not all munitions that can be destroyed in the T-10 blast chamber.

Warning

- Total explosive weight (donor charge and NEW of the projectile) must not exceed the equivalent of 10 lbs. HMX (13 lbs. TNT).
- Limit explosive items to a fragment hazard of less than or equal to an 81-mm mortar.
- Detonation of any munitions without an appropriate countering donor charge and an appropriate quantity of water in the chamber can result in structural damage and increased shrapnel hazard.
- Explosive items must be wrapped in sheet explosive.
- Only conventional high-explosive ordnance items can be destroyed; chemical, biological, or white phosphorous munitions should not be detonated in the T-10 system.

4.1 UXO Configuration Inside the Detonation Chamber

For UXO that do not need to be handled directly, a net is provided that can be suspended by hooks that are located on the interior wall of the T-10. Most conventional projectiles can be placed nose down into the pea gravel within the projectile platform provided. Diagrams are shown below in Figures 2 and 3.

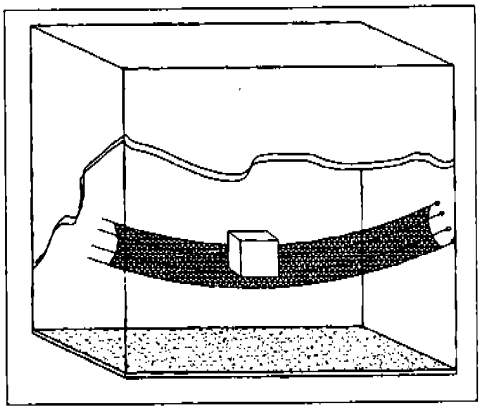

Figure 2. T-10 Net Configuration

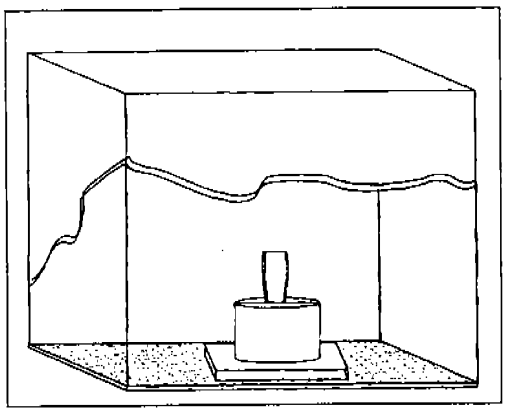

Figure 3. T-10 Conventional Munitions (81-mm)

4.2 Wrapping munitions with flexible sheet explosive.

To reduce primary fragment energies, munitions will be initiated using a donor charge consisting of flexible sheet explosive covering every portion of the munition from which primary fragments will emanate. For example, the entire body of an 81mm mortar projectile will be encased in sheet explosive because primary fragments emanate from the projectile body. However, it would not be necessary to wrap the tail boom or fins of this round. The weight of this donor charge will equal or exceed the weight of energetic materials in the munitions in the shot.

4.3 Destroying Shape Charges

To defeat shape charges within the T-10 the cone of the shape charge must be crushed to keep the jet from forming. Placing extra explosive sheet around the cone and initiating at that point will defeat the shape charge. (See Figure 4 below)

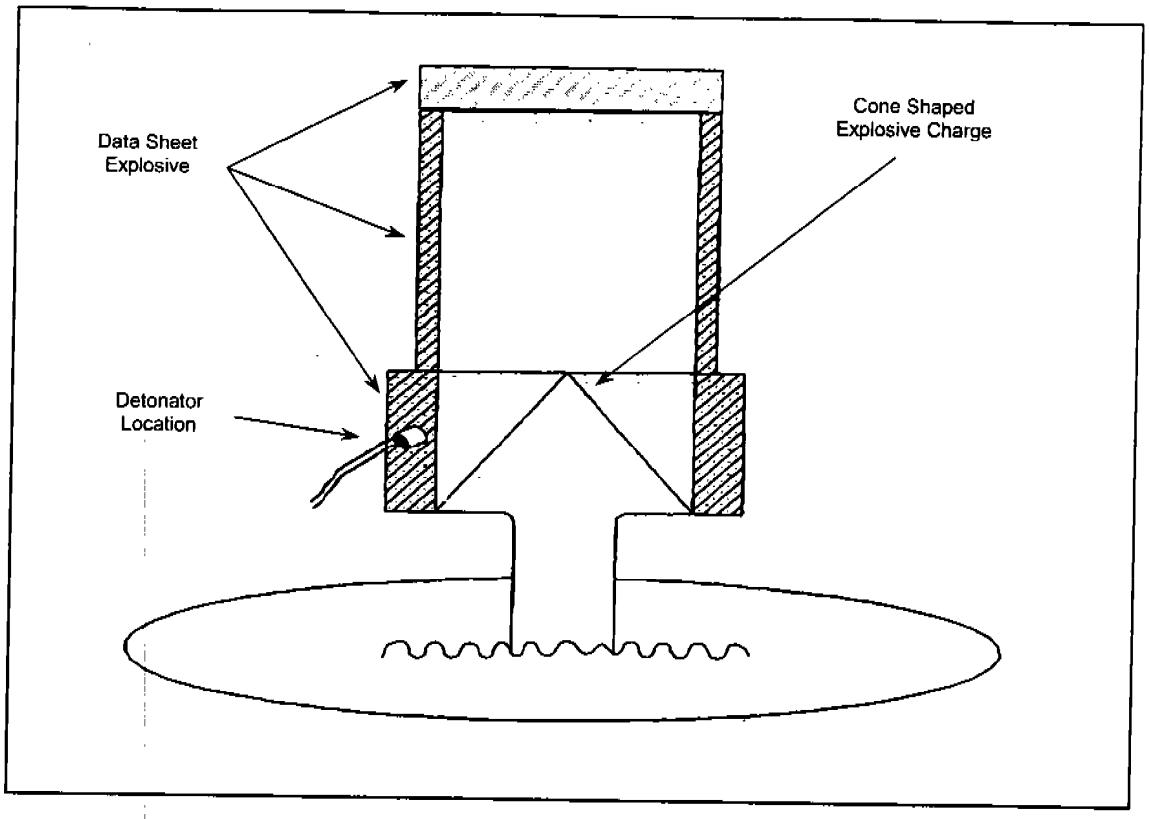

Figure 4. Defeating a Shape Charge

5.0 MAINTENANCE AND INSPECTIONS

Proper maintenance is essential for the T-10 Donovan Blast Chamber. Maintenance assures proper function of chamber components and extends the useful life of the system. All chamber personnel should be aware of the maintenance schedule and should assist in maintaining and inspecting the chamber system.

5.1 Maintenance Schedule

Note: The procedures presented below are suggested maintenance schedules. Site conditions and rate of shooting and nature of the munitions (UXO) destroyed have a large impact on the maintenance schedules. Maintenance procedures need to be developed after these factors are known. Regardless of the conditions, it is important to make interior inspections at a minimum of twice daily (every four hours).

5.1.a. Every 4 Hrs

1) Door hinges are to be lubricated at provided zerks using a good grade of gun grease.
2) Fittings should be cleaned before lubrication is attempted.
3) Inspect chamber for cracks or other structural damage.
4) Any system deficiencies identified requires immediate stoppage of operations of the T10 and these deficiencies should be communitcated to DeMil International immediately.
5) Deficiencies will be repaired by DeMil International or a DeMil International designated contractor.
6) Inspect Expansion chamber for cracks and bolding of the walls.
7) Deficiencies will be repaired by DeMil International or a DeMil International designated contractor.
8) Inspect APCU for cracks and bolding of any surfaces.
9) Deficiencies will be repaired by DeMil International or a DeMil International designated contractor.

5.1.b. Daily

1) Test Firing System.
2) Note the condition of door seal and replace as necessary. (The door seal is a silica caulk that can be purchase at any hardware store.)
3) Proper sealing will minimize any leaks from around the door.

5.1.c. Weekly or As Needed

1) Check sand level on top of chamber and add if necessary.
2) Access ports are provided at the top of the chamber.
3) This is usually considered a DeMil International level of maintenance.
4) A new chamber will need this weekly sand level inspection as some settling is expected. With continued shooting, this sand level inspection can be moved to monthly inspections.
5) Check gaps between armor plates for erosion of weld bead. If weld bead has eroded to the point where the inner wall behind the armor plates is exposed, weld on more bead to cover the exposed area.

5.1.d. Monthly or As Needed

s

1) Check armor plate for Shrapnel Erosion. 50% depth erosion on 50% of the surface area of the armor plate (11.5" X 11.5" x ½ " AR-500 Steel), indicates replacement of that plate. This erosion is evaluated visually. If the operator notices unusual levels of erosion, this should be brought to the attention of DeMil International who is responsible for this level of

maintenance. During operations, visual inspections will be done on the plates on a daily basis to determine wear. Once an obvious erosion pattern becomes apparent and sufficient, DeMil International will remove and replace the worn armor plate(s) and develop an inspection and measuring procedure for these plates.

2) Remove all pea gravel from blast chamber.
3) Refill with fresh pea gravel.
4) Remove all dust collected in expansion chamber.
5) All dunnage, baghouse dust, pea gravel must be characterized (by TCLP Analysis) for final disposition and disposal.

5.2 Operations Log Book

A logbook should be used to aid maintenance and assure that maintenance does occur at the proper intervals. The logbook is maintained by the shooter (operator) and provides for recording the following information: (See Example Sheets, next pages)

(Example Log Book Sheet)

T10 Daily Detonation Log

Operator's Name:_____ Date:_____
Team Members:_____
_____
_____
Contract Number/Project Number:_____
Project Location:_____

Daily Detonation Log

Shot #	Time	Munitions ID & NEW	Donor Charge Weight Water Weight	Comments
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Warning: Shooting the T-10 without an adequate amount of water properly placed in the chamber can cause increased pressures and temperatures which can lead to excessive wear and early structural failure.

Expansion Chamber Peak Pressures and Temperatures are automatically recorded by the monitoring system in production T-10s. The number of detonations should coincide with this monitoring system data. Discrepancies will need to be documented on a separate sheet of paper and included in this logbook.

Comments: _____
_____
_____
_____

(Example Logbook Sheet continued)

T-10 Daily Inspection and Maintenance Log

- ❑ Detonation Chamber Welds _____
- ❑ Detonation Chamber Walls _____
- ❑ Detonation Chamber Armor Plate (50% erosion requires replacement of the plate) _____
- ❑ Detonation Chamber Gaps between Armor Plate (weld bead in gap must cover inner wall). ___
- ❑ Detonation Chamber Door Seal _____
- ❑ Detonation Chamber Door Operation and Lubrication _____
- ❑ Expansion Chamber Welds _____
- ❑ Expansion Chamber Walls _____
- ❑ APCU Welds _____
- ❑ APCU Vessel _____
- ❑ APCU Access Ports Secured _____
- ❑ APCU Dust levels Checked _____
- ❑ Inspect all duct work connecting the system components _____
- ❑ Monitoring System Operational (production T-10s)_____
- ❑ Generator Operation, voltage and rpm (see Operations Manual)_____
- ❑ Air Compressor Operation (90 to 100 psi, see Operations Manual) _____
- ❑ Firing Set Tested _____
- ❑ Firing Wire Leg Wires Replaced (inside the chamber) _____
- ❑ Excessive Dunnage Cleared from Chamber if needed _____
- ❑ Pea Gravel Level Checked _____
- ❑ Projectile Platform Checked for proper placement, wear and refill with pea gravel _____
- ❑ T-10 Chamber Systems Energized and Operated prior to first Detonation _____

Comments _____

6.0 RECOGNIZING POTENTIAL CHAMBER FAILURE

The strength of the "Donovan Blast Chamber" technology lies in the robustness and redundancy of design. Every feature has been designed to mitigate and control shock waves and overpressure and to mitigate and control shrapnel hazard. There are certain early indicators of structural problems that can be routinely monitored. When a problem is indicated, investigation into the cause and corrective actions should be implemented. Repairs to chamber can be done and the chamber returned to service.

The following sequence of structural problems would become apparent with routine visual inspections:

1. Initial signs would be weld failure at the corners.
2. Followed by failure of the inner corners.
3. This would be accompanied by bolding of the walls between the structural members.
4. Continued shooting would lessen the integrity of the chamber.

If routine structural inspections are conducted and design parameters are followed to avoid over loading, catastrophic failure of the chamber is virtually impossible.

7.0 SUMMARY

This Explosive Safety Submission was developed at the direction of the U.S. Army Engineering and Support Center, Huntsville, Alabama. As a commercially developed technology, improvements will be developed and integrated into the system. As these improvements are made, this ESS will be updated.

All questions about this document should be directed to the U.S. Army Engineering and Support Center, Dr. Michelle Crull (256) 895-1653. Questions about the T-10 Transportable Donovan Blast Chamber should be directed to:

Mr. Kenneth A. House
DeMil International, Inc.
221 East Side Square
Huntsville, AL 35801
Tel/Fax: (256) 536-6885/519-6456
Email: kenhouse@demil.net

APPENDIX B

PATENT NUMBER 5,613,453

This patent depicts a similar but larger chamber; however, the patent depicts and protects the blast suppression technology that is common to all Donovan blast chambers.

APPENDIX D

DIAGRAMS OF THE T-10 TRANSPORTABLE DONOVAN BLAST CHAMBER AND THE TORIT CARTRIDGE SYSTEM DUST COLLECTORS

STANDARD OPERATING PROCEDURE

For Destroying Unexploded Ordnance and

Maintenance and Inspection for the:

T-10 TRANSPORTABLE CONTAINED DETONATION CHAMBER

"Donovan Blast Chamber"

September 25, 2001

Developed by:

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SOP QUALIFYING STATEMENT

This Standard Operating Procedure has been developed as a "Generic SOP". It is not intended to replace or act as a substitute for a Site Safety Plan and a more specific SOP based on site conditions and/or UXO types. This SOP should be considered a starting point for developing more detailed and specific SOPs.

WARNING

Only conventional high explosive munitions up to and including the 81-mm HE mortar round should be demolished in the T-10 blast chamber. Chemical/biological munitions should not be detonated in the Donovan Blast Chamber system.

GENERAL OPERATIONAL REQUIREMENTS

1. Utility Requirements

Power Requirements – 480 volts (3 phase) at 20 amps

Compressed Air - The T-10 Blast Chamber requires compressed air at a rate of 100 cubic feet per minute at pressures of about 120 pounds per square inch.

The latest model of the T-10 has a generator and air compressor supplied with the system.

2. Personnel Requirements

A minimum of two trained personnel is required to operate the chamber. This limits the throughput of the chamber somewhat. Higher throughputs will require additional personnel. These personnel should be trained in explosives handling and familiar with all safety procedures associated with handling explosives, ordnance and unexploded ordnance.

3. Training Requirements

DeMil International requires an intensive four-week training coarse for operating the T-10. This requirement may be shortened at the discretion of DeMil's Safety Director based on the level of training and experience of the proposed operators. Operators will be trained and certified by DeMil's Safety Director.

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Definitions

1. **Access Door** – This is the "front" door of the chamber. This door completes the blast chamber design when closed.

2. **Air Pollution Control Unit (APCU)** - Torit Downflo bag house air filtration device. Filters detonation gases down to 1 micron.

3. **APCU Dust** – Material captured by the APCU filter elements. Consist primarily of particulate material "dust" and accumulates in the bottom of the APCU and discharges into an open top 55-gallon drum. This dust should be assumed to be a "reactive hazardous waste" until analyzed and determined to be non-hazardous. Disposal should be in accordance with accepted local, state and federal environmental regulations.

4. **Chamber Operator** - Overall responsibility for safety, operation, and maintenance of the blast chamber. Inspects chamber. Correct operating procedures are followed. Insures maintenance procedures are followed.

5. **Chamber Safety** - Responsible for inspection of chamber after each detonation. Insures water bags are in place prior to the next detonation. Checks the condition of the Projectile Platform and insures that it remains filled with pea gravel. This person can be the senior chamber operator or the chamber operator.

6. **Contained Detonation Chamber** – (CDC) Double-walled with silica sand fill in the voids where actual detonation occurs.

7. **Deta Sheet Explosive** – PBX Explosive Strips. Detasheet is listed under specification MIL-E-46676 and DL 3139754, in addition, the following table applies:

Oz Per 20" Length	Thickness in Inches	Length in Feet	NSN	DODIC/NALC
14	.083	38	1375-00-036-0443	M980

U.N. PROPER SHIPPING NAME: Explosive, blasting, type D, UN0084
U.N. NUMBER UN0048
HAZARD CLASS: 1.1D
SECURITY CLASS: 2
REFERENCE NUMBER EX-9709049 EX-9709050
PRODUCT DESIGNATION/PART NUMBER PBX Sheet/Explosive Strips Donor Charge
SHIPPED AS: Two 20-pound rolls in a cardboard box, 40 pounds shipping weight.

*For additional information see Material Safety Data Sheet (MSDS) available from Donovan Commercial Industries, Inc. P.O. Box 909, 400 Williams Mine Road, Nortonville, KY 42442. Telephone: (502) 676-3792. The MSDS must be available on site at all times.

8. **Donor Charges** – PBX sheet explosive "Deta Sheet" manufactured for the Donovan Blast Chamber.

9. **Expansion Tank** – Single walled steel chamber that the CDC vents overpressure and detonation gases to.

10. **Exploding Bridgewire Detonators (EBWs)** - Part Number: RP-501. Manufactured by Reynolds Industries Systems, Inc. (RISI) is the detonator of choice for use with the Donovan Blast Chamber because of safety factors.

11. **Firing Legg Wire** – The section of firing wire that connects the Firing Wire Interface to the "Package" detonator.

12. **Firing System Safety Plug** – A "shorted" female electric plug that is plugged into the FS-61B Firing Set to insure that the firing system is disconnected and "Safe".

13. **Firing Wire** – 12-2 Non-metallic sheathed cable Type NM-B (Romex), commercially available.

14. **Firing Wire Interface** – Transfers the firing circuit through the chamber wall. This interface is located in the right hand side of the chamber. The interior interface is located at or just below pea gravel level and is identified with two (2) wing nuts and a protective metal shield.

15. **FS-61B** – Exploding Bridgewire Firing Unit.

16. **Misfire** – A misfire is a situation where a detonation is attempted but does not occur. Misfires are generally the result of a defect in the firing system. This defect can be found in the detonator, the firing wire, or the firing set.

17. **Monitoring System** – Computer controlled sensing and monitoring system capable of detecting and recording peak pressures and peak temperatures.

18. **Package** – UXO plus donor charge.

19. **Secondary Containment Door** - This is the outside "front" door of the chamber. It forms an airtight seal over the access door. It is connected to the APCU via a vynil pipe and provides negative pressure between the access door and the secondary door. Any fugitive emmissions from the access door are captured by the vacuum and vented to the APCU.

20. **Senior Chamber Operator (SCO)** is responsible for the successful accomplishment of the work on the project site. He directly supervises all site work and personnel and assures they are operating in a safe manner. He must assure that all personnel, to include visitors, are properly trained, qualified, equipped, and protected from the hazards associated with the work site and site operations. Senior chamber operators are required to meet the USACE qualifications of at least a UXO Tech II.

21. **Shooter** - Responsible for the safe detonation of cargo container. Insures proper function and maintenance of firing system. Connects detonator. Insures chamber is clear and cargo container is ready for detonation. Fires detonation system. Clears misfires and implements corrective action. The shooter can be the chamber operator or the senior chamber operator.

22. **Ultra Web Filter Element** – Name of the filter elements used in APCU.

23. **Water Bags** – Plastic Zip Lock bags used to hold quantities of water in strategic areas within the chamber.

Operation Number: 1 [On-site Placement of the T-10]

Step #	Description	Procedures and Specific Instructions
1	**Safety** The T-10 was designed to destroy designated munitions safely in most situations. However, care should be taken to select a site that affords the best protection to surrounding buildings, structures and population.	**Safety will be established on a Site-by-site basis based on the specific Site Safety Plan.**
2	**Site Requirements**	1. Select a site that has a reasonably level hard surface. The T-10 is a heavy piece of equipment and should be located on paved and/or compacted gravel areas. 2. Select a site in reasonably close proximately to UXO to minimize travel distances.
3	**Site Security**	1. The Site Safety Plan will establish security. 2. Site should afford proper security for the equipment.

Operation Number: 2 [Daily T-10 Pre-shooting Inspection]

Step #	Description	Procedures and Specific Instructions
1	**Ventilation System / Air Pollution Control Unit (APCU)**	1. Read and become familiar with the Installation and Operation Manual for the Torit Filter Cartridge System Dust Collectors. (A copy is provided). 2. Operate APCU by starting fans. 3. Observe APCU fan to insure operation. 4. If fan does not operate, check power source first. 5. Check fan-troubleshooting procedures provided by manufacturer. 6. Monitor exhaust. Exhaust should remain visually clean. If a leak develops, it will be first noticed as a puff of dust immediately after a cleaning pulse. 7. Monitor pressure drop. Equilibrium ΔP (Pressure drop across filter elements) is generally 3-4 inches on magnehelic gage but 1-6 inches is considered normal. 8. Adjust compressed air to 90 – 100 psi.
2	**Firing System Daily Test** Frequency of Firing System Testing will be determined by site conditions and throughput on the system.	1. Utilize the TA-10B test set and follow instructions provided (see test set instructions and Operation Number 2, Step 4 of this SOP). 2. Insure proper operations of this system. 3. If Firing System is not operating properly, check Operation 8 – Misfire Procedures.
5	**Lubrication** Frequency of lubrication will be determined by site conditions and throughput on the system.	1. Apply grease to Blast chamber door hinges daily. 2. Grease type: Any good quality high temperature and pressure grease.
6	**Visual Inspection of Chamber Interior** Frequency of Inspection will be determined by site conditions and throughput on the system.	1. Inspect interior ceiling and walls (including door interior) for cracks or damage that may hamper operations. 2. Observe shrapnel erosion looking for patterns of abnormal wear indicating a possible change in operating procedures and repairs. 3. Unusual wear or damage will initiate a higher level of inspection. 4. Cracks in welds will require **Dye Penetrant-Nondestructive Testing** MIL-STD-271F(SH), 27 Jun 1986, to determine the depth and extent of the damage. 5. Call DeMil International for this level of Inspection. (256) 536-6885

7	**Inspection of Pea Gravel**	1. Visual check the condition of the Pea Gravel conditions. 2. Pea Gravel erosion is dependent on the throughput of the system. 3. A minimum of 6 inches (12.5 cubic feet, 1100 pounds) of pea gravel is maintained on the T-10 chamber floor. The pea gravel is washed and screened to 3/8" diameter. (Call DeMil for information on ordering and replacement of pea gravel.) 4. Determinations need to be made about the amount of dunnage and how often it needs to be removed. Dunnage removal done on an "as needed" basis. 5. Larger pieces of dunnage can be removed with a garden rake.
8	**Projectile Platform Inspection**	1. Check for proper placement inside the chamber 2. Check for damage or unusual wear patterns. 3. Container should be filled with pea gravel.
9	**Detonator Storage**	1. DoD regulations require that detonators be delivered for half days scheduled detonations. 2. This can change from site to site and is usually addressed in a Site Safety Plan.
10	**"Deta Sheet" Explosive Storage** A day's supply will be stored in a designated safe area (to be determined by a Site Safety Plan).	See Site Safety Plan
13	**Silica Sand Levels** Frequency of Inspection will be determined by site conditions and throughput on the system.	1. DeMil International will perform this level of inspection before delivery of the T-10 to the site. 2. Number of shots and time on site will determine the next interval of inspection.
14	**Operations Area Readiness**	1. Inspect the entire operations area, check for cleanliness, and operational readiness. 2. Any problems noted from the previous days operation should be fixed at this time.
15	**Recognizing Potential Chamber Failure** **Important Maintenance and Safety Information**	**If any of these structural indicators are identified, stop operations of the T10 and call:** **DeMil International (256) 536-6885.** If routine structural inspections are conducted and

	The strength of the "Donovan Blast Chamber" technology lies in the robustness and redundancy of design. Every feature has been designed to mitigate and control shock wave and overpressure and to mitigate and control shrapnel hazard. There are certain early indicators of structural problems that can be routinely monitored. When a problem is identified, investigation into the cause and corrective actions should be implemented. Repairs to the CDC can be done and the CDC returned to service.	design parameters are followed to avoid over loading, and maintenance schedules are maintained, catastrophic failure of the CDC is virtually impossible. The following sequence of structural problems would become apparent with routine visual inspections. <u>Initial Structural Indications:</u> 1. Weld failure (cracks) at the interior corners. 2. Followed by failure of the interior corners (material displacement). 3. Accompanied by "bolding" of the walls between the structural members. 4. Continued shooting would lesson the integrity of the CDC.

Operation Number: 3 [Detonation System Testing]

Step #	Description	Procedures and Specific Instructions
1	**Firing Wire (Special Equipment)** •	Information: • 12-2 Non-metallic sheathed cable Type NM-B (Romex). Commercially available.
2	**Firing Wire Configuration**	Information: 1. Attached to the firing set output terminals is a 2-foot length of firing wire. On the running end of this wire is the Firing Wire Safety Disconnect. 2. The Disconnect is comprised of a male electrical plug, a female electrical plug, and a shorted female electric plug (Safety Plug). 3. When in the firing mode the female and the male plugs will be joined. At all other times the "Safety" Plug will be attached to the male plug to prevent accidental firing
3	**Detonation Circuit Test**	Procedure: 1. Place the TA-10B in the planned detonator position. 2. Trigger the firing set. (See Operation Number 5) 3. Test will determine whether sufficient firing current is available and verifies the integrity of the firing circuit. 4. Instructions are available with the test set.
4	**RP-501 Exploding Bridgewire Detonator** Information: • Manufactured by Reynolds Industries Systems, Inc. (RISI) is the detonator of choice for use with the Donovan Blast Chamber. • It has been determined to be the best product for this application due to the inherent safety of EBW detonators.	

6	**Arming and Firing the FS-61B Exploding Bridgewire Firing Unit** Information: • Developed and manufactured by Reynolds Industries Systems, Inc. (RISI). • Powered by 110V AC. • Used to initiate Exploding Bridgewire Detonators (EBW). • When armed, it generates a firing voltage of approximately 4,000 volts. • When this firing voltage is reached, the unit automatically discharges the energy at the output terminals.	**See Operation Number 6 "T-10 Detonation Sequence".**

Operation Number: 4 [Receiving and Verifying Identity of UXO Item]

Step #	Description	Procedures and Specific Instructions
1	**T-10 Personnel** **Warning:** **Only conventional high explosive munitions up to and including the 81-mm HE mortar round should be demolished in the T-10 blast chamber. Chemical/biological munitions should not be detonated in the Donovan Blast Chamber system. White phosphorus devices should not be detonated in this chamber (these procedures have yet to be developed).**	Information: • T-10 Operations Personnel are not involved with the identification and removal of UXO Items in the field. • UXO Remediation Personnel will deliver UXO Items that are determined "Safe to be handled" to the T-10 personnel. • UXO Item will not be stored or stockpiled in the T-10 Operations Area unless the Site Safety Plan makes provisions for this.
2	**UXO Determination**	Procedure: 1. Senior Chamber Operator will verify the identity of the UXO if possible. 2. Otherwise, best judgment (based on site historical information) will determine the SOP for destroying identifiable UXO Items. 3. UXO NEW will be determined. 4. Donor Charge amount will be determined by the UXO NEW. 5. Combined UXO NEW and Donor Charge weight will determine water weight. 6. It will be assumed that any UXO that is unidentifiable will be treated as a High Explosive Item.

Operation Number: 5 [Preparing UXO and T-10 for Detonation]

Step #	Description	Procedures and Specific Instructions
1	**Projectile Identification** **CAUTION:** **No chemical/biological or suspected chemical/biological weapons are to be destroyed in the CDC.**	As an additional safety step, recheck the identity of the projectile and the NEW of the projectile.
2	**Donor Charge Determination**	Procedure: 1. Every effort should be made to identify the UXO before detonation inside the T10. 2. Only qualified Senior Chamber Operators experienced in identifying UXO should make this determination. 3. The amount and disposition of the donor charge is determined by the munition (UXO) to be destroyed.
3	**"Package" Preparation**	Procedure: 1. Wrap the projectile in the "Deta" Sheet and secure with "Duct Tape". Base plate does not need to be covered. 2. Amount of "Deta" Sheet (weight) and specific procedures - To be determined by the O&E Item. 3. Site conditions and munition type will ultimately determine the nature of this operation.
4	**Water Bag Weight Determination**	1. As a general rule, the ratio of water weight to total package NEW is 1.5 to 1.0. This can vary. 2. DeMil International supplies water bags. 3. One large zip lock bag typically holds 1 lb. of water. 4. Water bags are suspended from hooks provided in the T10.
5	**Placement of Cargo Package into the CDC.**	1. The shooter/operator will place the package within the T-10 and attach the detonator. 2. The UXO Item will determine placement and configuration of the detonator. 3. Shooter will place suspend the water bags inside the T-10.

6	**EBW Detonator Boosting, Handling and Placement** **Important Safety Note:** The sequence of this EBW detonator boosting and placement procedure is very important and will not be changed. Any change in the sequence of boosting and handling of the EBW detonator could result in an unplanned detonation that could cause serious injury and/or death.	The chamber operator will perform the following: 1. Make sure that you have possession of the firing system "KEY" for the FS-61B firing set before you proceed. 2. Select an EBW detonator from storage. 3. Select a ¾" x 4" piece of "Deta Sheet". 4. Check to make sure that the firing set is disconnected from the chamber firing circuit interface before proceeding. 5. Reach into the CDC and attach EBW detonator to Firing System Leg Wire. 6. The EBW detonator is "Boosted" with the ¾" x 4" piece of "Deta Sheet" that is wrapped around the detonator body. It should remain in place without taping. 7. Place EBW into package and secure with duct tape. 8. Close the inner chamber door and secure. 9. Turn fan speed switch to the "HIGH" position. 10. Close vapor door and secure. 11. Close two small ball valves. 12. Open large ball valve to apply vacuum. 13. Attach FS-61B firing set to the chamber interface.

Operation Number: 6 [T-10 Detonation Sequence]

Step #	Description	Procedures and Specific Instructions
1	**Arming the FS-61B Exploding Bridgewire Firing Unit** **Note: The "Shooter" will have the "ARMING" key in possession at all times.**	1. Disconnect the "**Safety Plug**" (see step 2). 2. Connect the female and the male plugs. 3. Insert the "**ARMING**" key. 4. Turn to the "**ON**" position. 5. A "**RED**" light will illuminate.
2	**Firing the FS-61B Exploding Bridgewire Firing Unit**	1. Final visual check on the access door closure. 2. Final check on Ventilation system operations. 3. Check that fan speed is set on "HIGH". 4. Final visual checks that T-10 personnel are aware of and prepared for the imminent detonation. 5. Shooter yells, "**Fire in the Hole**" three times. 6. Shooter depresses and holds the "**FIRE**" button. 7. The system will energize then fire automatically.
3	**Disarming the FS-61B Exploding Bridgewire Firing Unit**	Disarming Procedure: 1. Release the "**FIRE**" button on the firing set. 2. Turn the "**ARMING**" key to the "**OFF**" position. 3. Remove the "**ARMING**" key from the firing set. 4. Disconnect firing wire plugs. 5. Connect the "**Safety Plug**". 6. Firing system is "**SAFE**"

Operation Number: 7 [Post Detonation T-10 Opening and Ventilation Procedures]

Step #	Description	Procedures and Specific Instructions
1	**Post Detonation**	Procedure: "Chamber Operator" will wait 30 seconds for the air pressure in the CDC to equalize before the access door is opened.
2	**CDC Ventilation**	Procedure: 1. Open ball valve of compressed air supply to add clean air to the T10. 2. Open two small ball valves on vapor door. 3. Let chamber purge for approximately 30 seconds. 4. Close large ball valve to release vacuum on vapor door. 5. Open vapor door. 6. Unseal the access door and open carefully allowing the smoke and dust to clear, and clean air to be drawn into the T-10. (This minimizes fugitive air emissions) 7. Turn fan speed switch to "LOW"
3	**Safety Check**	Procedure: 1. Check to see that the UXO Item has been destroyed. 2. Look for any unusual wear on CDC armor plates. 3. Make determinations that T-10 is "Safe" for the next detonation. 4. Perform visual inspection (Recognizing Potential Chamber Failure). 5. Any cracks in any of the welds require dye testing to determine the depth and length of the crack.
4	**T-10 is ready to start detonation cycle again.**	

Operation Number: 8 [T-10 Misfire Procedures]

Step #	Description	Procedures and Specific Instructions
1	**Misfire** Definition: A misfire is a situation where a detonation is attempted but does not occur. Misfires are generally the result of a defect in the firing system. This defect can be found in the detonator, the firing wire, or the firing set.	1. Upon misfire, immediately inform detonation chamber personnel that there has been a misfire. 2. Note time of misfire. 3. Immediately attempt to fire the detonator again. 4. If misfire occurs again, turn "ARMING" key to "OFF" position. 5. Remove "ARMING" key from firing set. 6. Follow Firing Set Disarming Procedures (See Operation Number 5, Step 3)
2	**Waiting Period**	**Wait thirty (30) minutes before opening the CDC doors.**
3	**Clearing Misfire**	Render-Safe Procedure: 1. Evacuate all nonessential T-10 personnel to a safe distance. 2. A Senior Chamber Operator will open T-10 door. 3. A Senior Chamber Operator will remove disconnect and detonator. 4. Situation and munition will warrant the appropriate activity on the case-by-case basis. 5. "Bad" detonators should not be stored. They can be destroyed in the next detonation. 6. Inspect connection of the detonator leg wires to the firing wire.
4	**Removal of Munition**	Procedure: 1. If malfunction cause is not readily apparent, remove UXO Item from the T-10. 2. If detonator is suspected cause of malfunction, that suspect detonator can be destroyed in the next detonation. 3. Do not remove UXO Item from the T-10 until the detonator is removed from the package.
5	**Misfire Assessment**	T-10 personnel should perform a quick inspection of the T-10 to determine the cause of the misfire. Inspections should include: 1. Donor charge 2. Detonators 3. Detonator Wire 4. Detonator Set 5. Power Supply

6	**Corrective Action** Corrective Action will be determined from the Assessment of the misfire and on a case-by-case basis. Site Safety Plan will determine these procedures on a Site-by-site basis	
7	**Test Fire Detonator Firing System**	See Test Firing Procedures: (Operation Number 3) **If system is "OK":** 1. The detonator or detonator connection is the problem. 2. Replace detonator. 3. Check firing wire connections. **If system tests "NO GO":** 1. Inspect firing wire for broken leads. 2. Inspect firing wire plugs for lose or broken connections. 3. Inspect FS-61B output terminals for proper connection. 4. Inspect FS-61B input terminal for proper connection. 5. Attach TA-10B (with 10-foot leads) to the FS-61B and test function. 6. If defect is found during these checks repair or replace the deficiency.

Operation Number: 9 [Area Cleanup and Housekeeping (Site Specific)]

Step #	Description	Procedures and Specific Instructions
1	**Good House Keeping** Information: This part of the SOP is Site Specific. The Site Safety Plan and common sense will guide the development of the SOP.	1. Provide for trash disposal. (Nonhazardous) 2. Waste should be disposed off on a daily basis. 3. All PBX sheet explosive should be accounted for at the end of each shift (day). 4. No PBX sheet explosive or detonators (good or bad) will be disposed of in the trash. 5. Area should remain free of obstacles and barriers that would prohibit personnel from safely performing their jobs. 6. Area should remain free of obstacles and barriers that would restrict evacuation of the area. 7. Site Safety Plan will determine more specific details.

Operation Number: 10 [Daily T-10 Maintenance]

Step #	Description	Procedures and Specific Instructions
1	**T-10 Lubrication and Controls**	1. Check CDC door hinges for proper lubrication. 2. Lubricate the access door with a good quality high temperature and pressure grease. 3. Controls for the T-10 are limited to the Firing Set (see Detonation System Testing Procedures in Operation No. 3).
2	**T-10 Air Pollution Control Unit** **CAUTION**: • Disconnect electrical power before servicing any electrical components. • Shut off and bleed compressed air supply before servicing any compressed air components. • No welding should be performed inside the unit without fire protection. • Some worker exposure is to APCU dust and debris is inevitable; the use of appropriate respirator and protective clothing is strongly recommended.	1. Check air compressor psi. (Adjust air pressure to 90 – 100 psi) 2. Check condition of filters. If replacement is warranted see Installation and Operation Manual and Operation No. 11 of this SOP.
3	**Test Fire Detonation System** Information: • Test Firing System daily with the TA-10B Test Set. (See Operation No. 3) • Misfires may require additional testing above and beyond daily maintenance.	
4	**T-10 Interior Walls and Ceiling Inspection**	(See Operation Number 2 of this SOP)
5	**Check Sand and Pea Gravel**	(See Operation Number 2 of this SOP)
6	**Firing Wire Replacement**	Replace interior firing wire as needed.
7	**Cleaning the T-10 Expansion Chamber** Past experience has shown that the waste material in the expansion chamber is "Nonreactive" waste. **Note:**	Cleaning frequency to be determined. It is recommended that this procedure by conducted by trained DeMil International personnel. Suggested Clean Out Procedure: 1. Material will be characterized by TCLP analysis prior to removal. Otherwise the

	If the hazardous/nonhazardous characteristics of the Expansion Chamber dust and debris are not known, assume that the material is a "Reactive" hazardous waste.	material will be treated as "Hazardous Materials". 2. **Caution:** Hazardous "Reactive" material may require modified procedures that will need to be developed. 3. The following procedure can be used for nonhazardous material or hazardous "nonreactive nonflammable" material 4. Shut down all T-10 system components. (Air compressor, hydraulic pump, electrical to the Air Pollution Control Unit) 5. Open access panel to the expansion chamber. 6. Using appropriate equipment (vacuums) remove all dust and debris from the expansion chamber. 7. Deposit material into an appropriate container for disposal.

SAFETY AND HEALTH HAZARDS

Special Conditions: Until the characteristics of the APCU dust generated from the detonation of these munitions can be determined, the dust should be treated as a "Reactive" hazardous waste and handled with caution. If the dust tests to be non-reactive it can still contain "Heavy Metals" with can seriously impact the health of personnel that are exposed. Once an adequate amount of dust can be collected and analyzed (TCLP Analysis) than handling and disposition of the dust can be determined. This characterization can be munition specific.

Operation Number: 11 [Dunnage Removal and Disposal]

Step #	Description	Procedures and Specific Instructions
1	**Dunnage**	To be determined on a Site-by-site basis. Information: • Dunnage from the course of operations of the T-10 will consist of metal shards, shrapnel, and other metal objects that will vary in size considerably. • The procedures and frequency for removing this dunnage will be determined when there is sufficient dunnage to justify removal. • Accumulation of the dunnage is expected and should not be removed until it effects T-10 operations or that T-10 decontamination is required.
2	**Dunnage Removal, Characterization and Disposal**	Procedure: 1. Personal involved with this activity should wear appropriate protection clothing and respirators. 2. All efforts should be made to minimize personnel exposure to dust and contamination. 3. Using protective gloves, all efforts should be made to protect personnel from the sharp edges of the shrapnel and dunnage. 4. Dunnage can be removed by hand or with a garden rake or in some cases portable electro-magnets. 5. Dunnage will be deposited into an open top 55-gallon drum or a roll-off box. 6. Final characterization and disposition will be site and munitions specific.

Draft (Proposed) Appendix A – Destroying White Phosphorus (WP) Munitions

From the Merck Index, Twelfth Edition (an Encyclopedia of Chemicals, Drugs, and Biologicals)

"White Phosphorus is a colorless or white transparent, crystalline solid, waxy in appearance, darkens on exposure to light. Sometimes called Yellow Phosphorus; color due to impurities. When exposed to air in the dark; emits a greenish light and gives off white fumes. Ignites at 30° C in moist air; ignition temperature is higher in dry air. Caution: handle with forceps. Keep under water. The fumes and the element itself are poisonous."

White Phosphorus munitions present unique demilitarization challenges because white phosphorus is an air/moisture reactive material (metal). There are more concerns about fire hazard then with conventional high explosive munitions. Oxidizing the white phosphorus becomes the principal objective. Increasing the heat insures more complete oxidation. This is accomplished by reducing the ratio of water to total Net Energetic Weight (NEW) of the explosive package and increasing the NEW of the donor charge in relation to the WP munition filler weight.

The oxidation of WP forms P_2O_5 (Phosphorus Pentaoxide, solubility of 7.6×10^{-10}), which with water forms phosphoric acid. Pea gravel and pea gravel dust should function to neutralize this acid.

Change in Standard Operating Procedure for WP Munitions:

1. Use reduced water to total NEW/filler ratio of 0.5 to 1.0 by weight (normal ratio is 1.5 to 1.0 by weight).
2. Explosive to filler ratio changes to 4.0 to 1.0 by weight (normal ratio is 1.0 to 1.0 by weight).
3. After each WP shot "Rake the pea gravel in package platform and on blast chamber floor in insure complete oxidation of WP.
4. Between each WP shot, shoot a 2-pound NEW or equivalent high explosive shot.

Appendix B – T-10 Daily Detonation Log

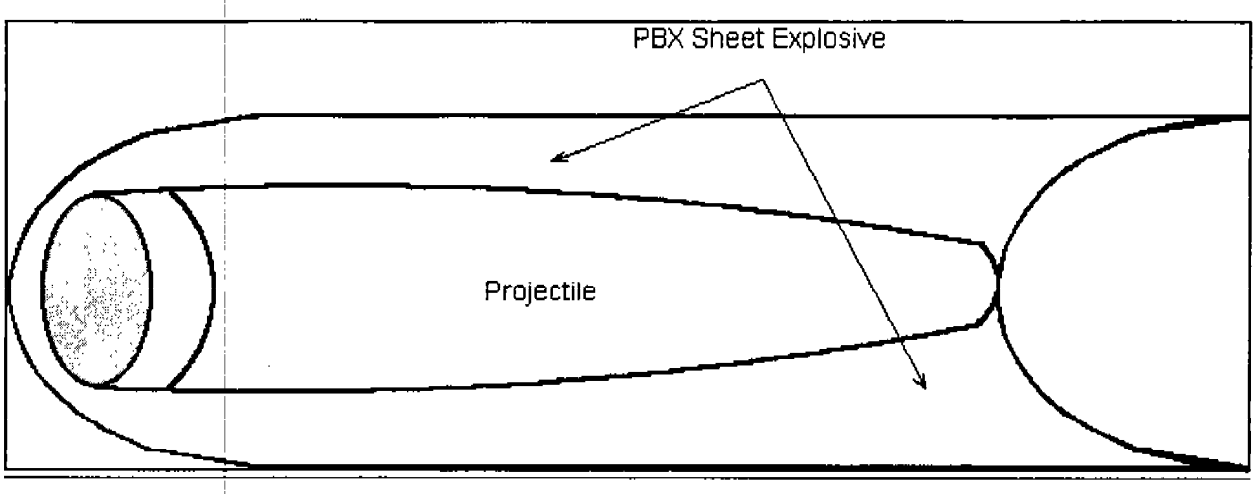
Operator's Name: _____ Date: _____
Contract Number/Project Number: _____
Project Location: _____
Team Members: _____

Shot #	Time	Munitions ID & NEW	Donor Charge Weight Water Weight	Comments
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

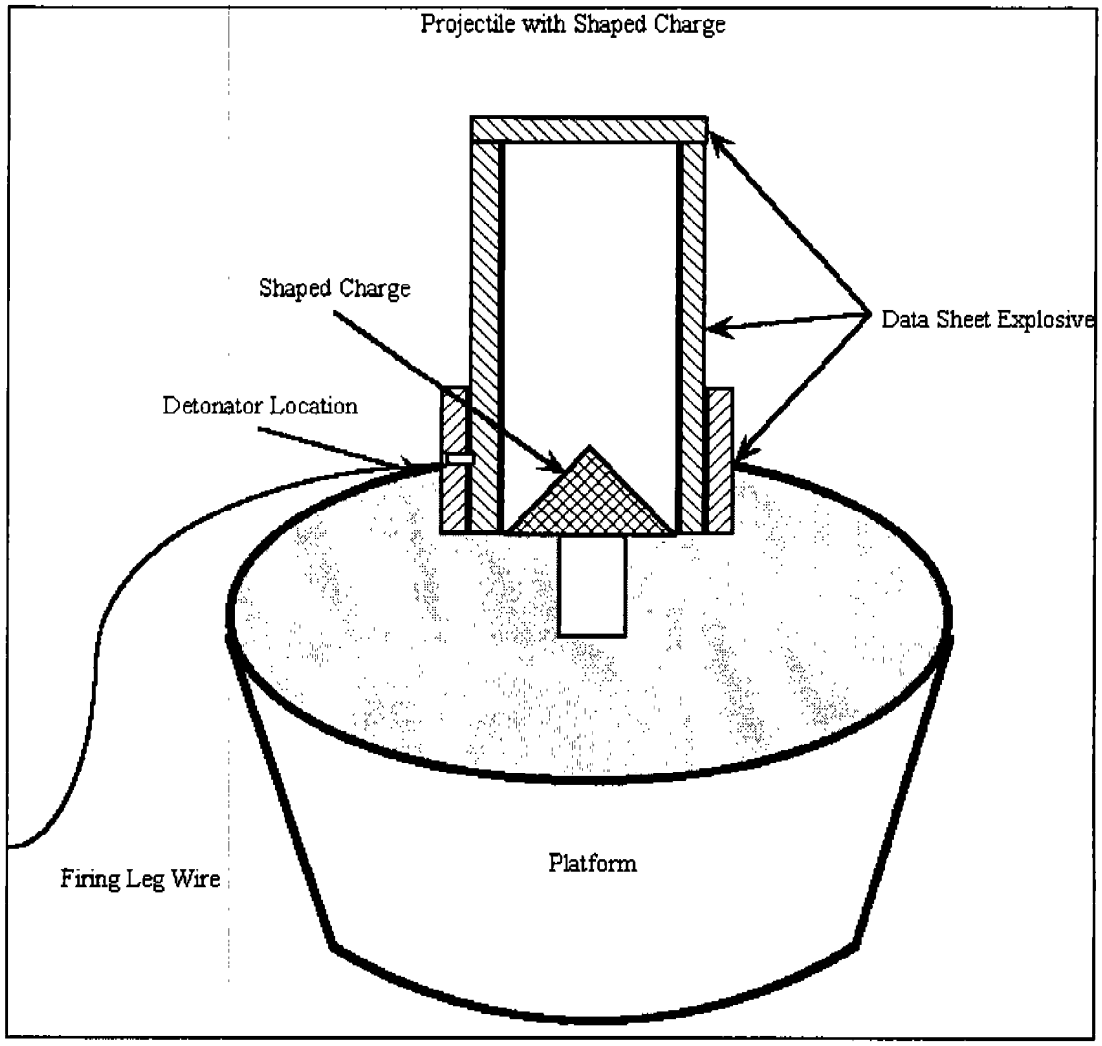
Expansion Chamber Peak Pressures and Temperatures are automatically recorded by the monitoring system. The number of detonations should coincide with this monitoring system data. Discrepancies will need to be documented on a separate sheet of paper and included in this logbook.

Comments: _____

Appendix C – Wrapping UXO with PBX Sheet Explosive



Defeating Shaped Charge



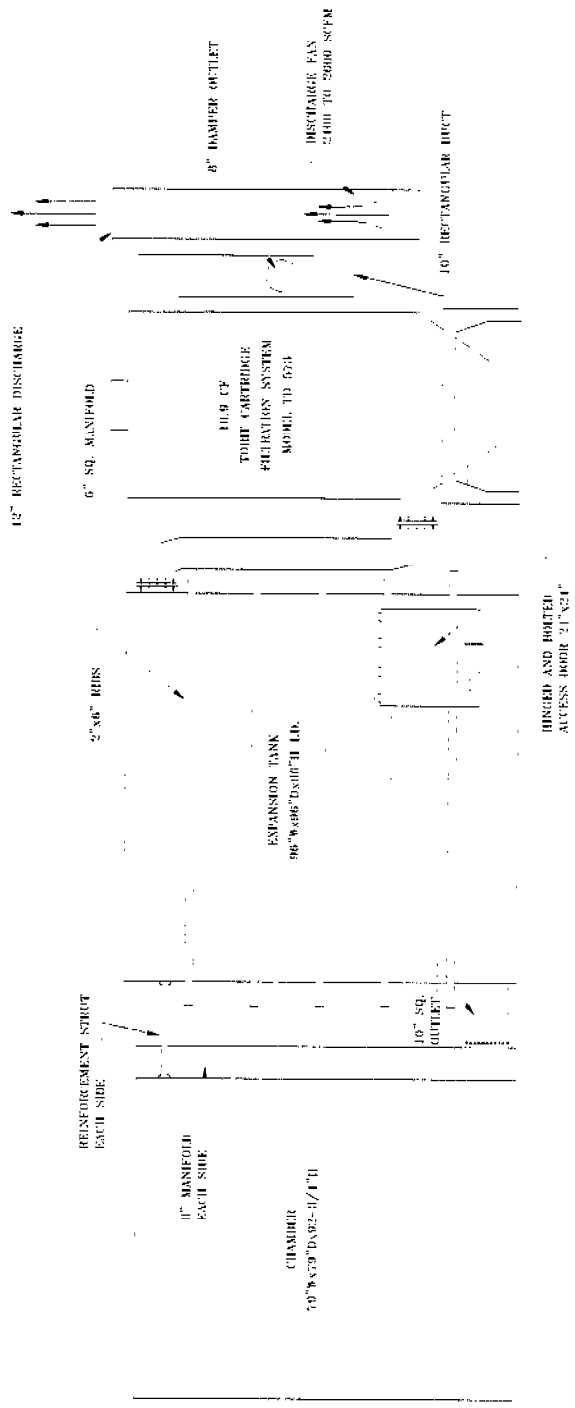


Figure 1. Line Diagram of the T-10 Donovan Blast Chamber at MMR

STANDARD OPERATING PROCEDURE
3RD PARTY QUALITY ASSURANCE

GENERAL

The Project Quality Assurance (QA) shall entail ordnance and explosives oversight and three geophysical related tasks: (1) an audit of the geophysical survey data collected; (2) detection performance quality control (QA) verification of 25 percent of the point cleared grids; and (3) performance of a resurvey of at least five (5) percent of the investigation area. These activities will include a daily audit of tasks performed by the OE Contractor.

ORDNANCE AND EXPLOSIVES OVERSIGHT

The QA Contractor will be responsible for oversight of all OE operations to be implemented by the Remediation Contractor. The QA Contractor will evaluate conformance to the OE plans by performing audits, surveillance, and reviews of work processes and acquired data using the OE QA On-Site Check List provided as Enclosure 1. The QA Contractor will report to DTSC and has the authority to require corrective actions and stop work, as needed, to ensure compliance with OE plans.

- Review and document the Contractor's daily activities for compliance with the approved plans for the site.
- Conduct daily inspections and document of field activities to ensure work is conducted in accordance with (IAW) OE RDD.
- Coordinate any changes required in MSDs and/or the Explosive Safety Submission.
- Verify that any changes to an MSD are done IAW Appendix C of the OE RDD.
- Monitor daily safety routines and document conformance to the Appendix F of the OE RDD.
- Participate in daily safety briefings during all phases of the project.
- Observe all field operations (monitor removal actions).
- Oversee, by daily inspection, the OE contractor to verify all removal actions are conducted IAW the OE RDD.
- Review field changes with site/project team, DTSC, and USACE.
- Attend Preparatory Meetings.
- Verify MSDs are appropriate for all Sectors.
- Place Blind Seeds in grids as directed by DTSC and USACE .
- Review all 'Safe to Move' determinations.
- Observe demolition operations to include Donovan Chamber, ensure all demolition operations are conducting IAW the OE RDD.
- Conduct a 10% QA Search Effectiveness audit of all grids submitted by the OE Contractor for audit using a magnatometer (i.e., Schonstedt) detector and submit 948 report for each grid
- Analyze point clearance data and participate in decision to go to area wide clearance.
- Monitor Project Conformance Audit Schedule (Appendix H of the OE RDD).
- Review dig selection process with Geophysical QA.
- Provide copy of daily QA Report to USACE OE Safety Specialist and DTSC.
- Provide daily Team assignment roster at the start of each work day to USACE Safety Specialist.

The QA Contractor will adhere to the safety and health requirements contained in the OE plans. During all field operations, the QA Contractor will perform UXO avoidance procedures. The QA Contractor will not conduct intrusive operations other than the burial of QA targets. The specific OE safety and health requirements that will be monitored by the QA Contractor are contained in the following regulations:

- EP 385-1-95a, Basic Safety Concepts and Considerations for Ordnance and Explosive Operations.
- EP 75-1-2, UXO Support during HTRW and Construction Activities.
- EM 1110-1-4009, Ordnance and Explosives Response.
- EM 385-1-1, U.S. Army Corps of Engineers Safety and Health Manual.
- DoD 6055.9 STD DoD Ammunition and Explosives Safety Standards
- ATF 5400.7 Federal Explosives Law and Regulations
- EP 1110-1-18 Ordnance and Explosives Response
- DA Pam 385-64 Ammunition and Explosives Safety Standards
- Applicable 60 Series Publications
- ER 385-1-95 Safety and Health Requirements for Ordnance and Explosives Response Actions
- AR 385-64 US Army Explosives Safety Program
- Applicable USACE HNC Guidance documents.

GEOPHYSICAL DATA COLLECTION AND PROCESSING

The QA contractor will perform an audit review of the geophysical data collected for each sector. This audit will initially comprise an inspection and review of 100 percent of the collected data. Following review and acceptance of the data by the QA Contractor, the California Department of Toxic Substance Control (DTSC) and the USACE, the QA audit will be reduced to 50 percent of the data, to be followed as recommended by the QA Contractor and approved by the DTSC and the USACE, as recommended by the QA Contractor and approved by the DTSC. These inspections will include checks of instrument standardization documentation, completeness of the mapping coverage, and the representativeness of the anomaly sources. Additionally, the QA contractor will re-process at least 10% of the geophysical data using the *Geosoft Mapping and Processing System and OE Target Analysis.*

The QA evaluation will include:

- Review of OE Contractor daily field QA documentation (e.g., maps, field notes)
- Review of standardization results (instrument precision)
- Derivation of data statistics and measurement coordinates (location accuracy)
- Posting of data stations for each segment (survey/coverage completeness)
- Generation of contour/image/profile plots (representativeness/reasonableness)
- Comparison of field anomaly map, digital data image, and OE sampling results for each area investigated (representativeness). This review may include assessment of previously generated geophysical data.
- Verifying geophysical data is generated and delivered in accordance with the agreed upon schedule and that the OE Contractor is maintaining the quality control procedures and schedules for data acquisition, processing, and interpretation specified in the Tourtelot Project Site Ordnance and Explosives Remedial Design Document (OERDD).

QA processing will include production of representative profiles. The profile images will be compared to the data processed imaging of the OE contractor over the same survey area to determine correlation between identified potential OE anomalies. The compared anomaly lists will be tabulated and presented to the Granite Project Coordinator, DTSC, USACE, and the OE contractor.

Geophysical Data Evaluation

The QA Contractor will review the field data daily to identify unusable or incomplete data delivered for any transect. Field data will be reviewed to ensure complete coverage, measurement precision, representativeness, and geophysical reasonableness of the survey results. The QA Contractor will forward to the DTSC and USACE copies of all data, maps, and images received from the OE Contractor in accordance with the same delivery schedule as is delivered by the OE Contractor.

The QA contractor will ensure that a daily log and a field sketch map of mapped survey grids and paths are made as the geophysical data collection progresses. All activities related to geophysical data collection are to be documented in the daily log. Field maps will note date/time of the survey, area covered, and the location and description of potential noise sources that could affect interpretations.

Daily logs will record:

- Morning pre-survey checks of instrument and batteries
- Safety and planning briefing
- Identification of traverse segment(s) to be mapped
- Equipment set-up
- Definition data file names
- Initialization of data logger(s) to record geophysical response
- Performance of instrument standardization
- Any areas not surveyed due to site specific conditions
- Delivery of digital survey data to the Site Manager (including, raw, basic processed, or final processed data).

An independent review and verification of the geophysical data will be performed by the QA contractor. Data will be audited by processing data from randomly selected grids using *Geosoft Mapping and Processing System and UXO Target Analysis*. QA processing of digital data will include production of representative profiles. The raw data from the data loggers will be used to create image plots; the data will not be filtered unless background noise levels are excessive (this will be determined during the first week of the field effort). The images will be used as a QA tool to compare visually discriminated locations with those anomaly locations identified by the automated (digital) target picking routines used to generate the anomaly "dig" lists.

The basic processed and final processed data will undergo the same review (data analysis and generation of image plots). The image maps provided by the OE Contractor must have areas not surveyed, due to site specific conditions (vegetation, terrain, or other physical obstacles), clearly delineated.

The basic processed and final processed data files will be checked to ensure that each file has a header that contains, at the least, the following information:

- Geophysical Subcontractor
- Sensor – name, model of instrument, serial numbers
- Start date for acquisition/processing of data in file
- End date – date data acquisition/processing complete
- Survey line spacing
- Data density along traverse
- Survey block of grids encompassed by data in file
- Name of raw data file(s) for data in file
- Begin point (easting) for data in file
- Begin point (northing) for data in file
- Number of data columns in file, followed by description of each data column
- Column for each data channel (Z1, Z2, . . . Zn)
- Comments – site/grid specific comments
- Corrections – describe corrections/edits, if any, applied to data during processing. Cross-reference separate data processing files as required.

The field review will ensure that precise measurements of the geophysical response were obtained by verifying that instrument performance during standardization fell within the established ±10 percent acceptance range. Daily standardization measurements and results are to be completely documented in the daily field log. The daily logs will be reviewed to ensure proper implementation of the quality controls.

The State Plane coordinates recorded for each transect will be compared with a master listing to ensure that the sampling data are accurately located within the study area. The field logs will also be reviewed each day to verify that data were collected following a continuous progression along the transects. If the survey progression was interrupted for a particular segment because of terrain or other considerations, the causes of the deviation and the actual mode of progression should be fully described in the daily log notes.

The field review will ensure that the transect investigation was complete by verifying that the data volume for each receiver array is comparable (±1 percent) and that the spatial data density (measurements per unit distance) is representative of the mapping effort described in the daily log. Field notes will be compared to the downloaded digital file data to assure correspondence between transects searched and transects recorded.

Anomaly Discrimination

The QA contractor will review anomaly picks to ensure responses with characteristics that could be representative of targets of interest (e.g., OE projectiles) are discriminated in the data. The anomaly discrimination process will not eliminate any anomalies from the investigation other than those that are clearly not associated with OE, such as long linear trends, obvious geologic features, or responses that are demonstrably (e.g., through field notes) caused by surface artifacts, based on the available geophysical, visual, and historical data. The data review will ensure that anomalies of concern (those with a signal-to-noise ratio (S/N) sufficient to discriminate target responses in the data) are identified. Minimally, the S/N should be at least 1.5 times greater than the background threshold level.
The hard copy and digital "Dig-Sheets" provided by the OE Contractor will be reviewed for inclusion of the following:

- Project Site
- Date data acquired
- Date final data processed
- Responsible Geophysicist
- Sector/Area
- Grid Number/Transect
- Anomaly Number
- State Plane Coordinate Location (northing and easting)
- Anomaly Location Reacquired and Marked
- Estimated Depth to Top of Item.
- Actual Depth to Top of Item
- Maximum Amplitude of Original Anomaly
- Maximum Amplitude of Reacquired Anomaly Location

Performance Criteria.

Locational Accuracy. **The QA Contractor will verify that** survey lane segments correspond to the areas actually investigated by the geophysical teams. Further, the data acquired along each survey lane will be checked to verify they are accurately located relative to State Plane coordinates in order to assure proper characterization of the sectors.

The State Plane coordinates recorded for each transect will be compared with a master listing to ensure that the sampling data are accurately located within the study area. The field logs will also be reviewed each day to verify that data were collected following a continuous progression along the transects. If the survey progression was interrupted for a particular segment because of terrain or other considerations, the causes of the deviation and the actual mode of progression should be fully described in the daily log notes and in the header of that particular grid survey file. Plots of the survey progress will be updated each day and transferred to a site map to aid in tracking the actual search areas.

Instrument Precision. **The QA Contractor will verify that the** proper operation and function of the geophysical survey system is checked and documented in the field log each day by a standardization process prior to the beginning and at the end of each geophysical survey episode (defined as before survey segment begins and prior to turning the equipment off at the end of any survey segment). Instrument standardization responses will be checked to verify that the responses vary by no more than ±10 percent of standard response obtained for each deployed geophysical system. Acceptance range will be specified at ±10 percent of the standard response (calculated mean residual anomaly). Field log entries will be inspected to ensure instrument performance meets the standardization criterion. The standardization data recorded by the geophysical survey team will be evaluated to ensure that the system meets the specified survey requirements.

Completeness. **The QA Contractor will verify that the** data were collected in such a manner that a data mesh specific to the targets of concern could be generated for the transect survey. Field logs will be reviewed, and the QA Contractor will post digital data to a segment track map to determine if there are any missing data stations not accounted for in the field notes.
The field review will ensure that the transect investigation was complete by verifying that the data volume for each receiver array is comparable (±1 percent) and that the spatial data density (measurements per unit distance both longitudinally and transverse to the survey line) is representative of the mapping effort described in the

daily log and as specified in the OE RDD. **The QA Contractor will verify that the** Survey data was captured such that 98 percent of measurements at increments of 1 foot or less along each transect were recorded. Field notes will be compared to the downloaded digital file data to assure correspondence between transects searched and transects recorded.

Geophysical Reasonableness. The QA Contractor will review the recorded geophysical responses to verify that they reflect the physical properties of conductive materials in the near-surface. Data will be inspected to ensure anomaly responses caused by small, finitely bounded concentrations of conductive soils or minerals are differentiable in the recorded data. Noise levels in the data will be analyzed to ensure that they are sufficiently low to allow adequate signal-to-noise differentiation of pertinent anomalies, based on static and translational noise tests conducted during the equipment field tests.

Geophysical Data Management. The QA Contractor will review and ensure that the geophysical data are properly acquired, processed, interpreted, and stored in a comprehensive manner. This includes verifying the completeness and accuracy of any informational databases related to the geophysical operations. Along with the acquisition, processing, and interpretation databases, the QA Contractor needs to ensure that the OE Contractor is tracking deliverables of raw, basic processed, final processed, and all quality control data (geophysical, positional, and OE investigation), and that they are tracking their own quality assurance evaluations.

QUALITY ASSURANCE CONFIRMATION RESURVEYING

The QA Contractor will also resurvey at least five percent (5%) of the investigated area with the same or similar geophysical instrumentation to ensure that the OE Contractor-acquired data are representative of the site. Approximately ½ of the mapping will be completed prior to intrusive investigation and the remainder of the mapping will be performed after the intrusive investigation has been completed.

DETECTION PERFORMANCE

Blind Seeding

Performance Objectives for this remediation require 100 percent detection of all seeded QA targets. The QA targets will be planted prior to geophysical mapping of the individual sectors at the project site. The QA Contractor will seed each 100-foot by 100-foot grind in Sector 10B and 25 percent of the 100-foot by 100-foot grids in the remainder of the Project Site with one (1) or more inert OE items. Seeded targets will be placed in a horizontal plane at or above the maximum reliable depth of detection (MRDD) for a 37mm (or 60mm, as appropriate to each sector of the site) projectile, as determined at an equipment test plot on the Tourtelot Project Site.

Grids to be seeded within each sector will be randomly selected using a random number generator. The location of each seeded target will also be randomly generated using grid northings and eastings with a table of generated random grid coordinates. For each seeded QA target, the position (in CSP grid feet, NAD83) +/- 4 inches, the depth (+/- 0.10-inch) and the orientation (axial bearing +/- 5 degrees) will be determined and recorded in an electronic database.

OE avoidance procedures will be followed when the targets are planted. The QA Contractor will record and report the target position using a DGPS or RTK GPS with better than 4-inch horizontal accuracy.

Verification

The QA Contractor will be given the recovered inert OE items, the coordinate locations, and the depths of each QA target discovered by the OE Contractor during the point clearance OE removal. The OE Contractor will inform the QA Contractor when the point clearance of each grid is complete. The QA Contractor will compare the list of discovered QA targets with the QA database. Failure to find any QA targets in a given grid at or above the MRDD constitutes a detection failure for the particular grid. Such failures will be reported to the Granite Project Coordinator, DTSC, USACE, and the OE Contractor and the procedures described in the OE RDD (Chapter 6) will be followed.

Metal Detector Checks

Prior to OE escort or surface activities, a check bed as described in Section 4.10.1 will be established by the OE Contractor. Metal detectors are checked against the source to ensure they are operational and capable of detecting targets of concern.

The QA Contractor will verify that the daily logbooks document that each deployed metal detector was checked daily against a known metallic anomaly source. To ensure that instruments remain operational during field operation, all instruments will be checked by the Senior UXO Supervisor against a surface anomaly (i.e., keys, watch, leatherman). This check will be recorded in the logbooks and verified by the QA Contractor.

RECORDS MANAGEMENT

The QA Contractor will ensure that all daily notes are recorded in bound field notebooks, digitally captured data copied to archive disks, and that all data files are accompanied by Microsoft Word documents detailing file content, file naming, and data processing performed on the field data.

QUALITY ASSURANCE SUMMARY

The QA results of the OE clearance will be tracked on a master spreadsheet that will tabulate survey area identification, coordinates, and date surveyed. A **Weekly QA Summary** will be prepared and submitted to Granite's Project Coordinator, DTSC, USACE, and the OE Contractor. The summary will include the items delineated in the following subsections.

Precision

A mean deviation from the standard response will be calculated for each instrument used. This will be reported in a progressively updated table.

Accuracy

Any discrepancies in positional or locational accuracy of the data noted during the field review will be described, including steps taken to correct or resolve any such QA issues.

Completeness

The percentage of coverage of each investigated segment will be tabulated. Significant lack of coverage (> 2 percent missed) will be flagged and annotated with the steps to be taken to resolve the missed coverage. Unavoidable obstacles will have been mapped on the field sketches and should result in direct correspondence with missing data. The steps that are presented in Section 4 of the OE RDD will be followed if data shortages are detected.

Reasonableness

Any variations or results not compatible with prior results or expectations will be reviewed with the OE Contractor geophysicist to determine causative features that may be present. These field contacts will be summarized and included in the weekly QA summary report.

Representativeness

A table will be developed and progressively updated that presents pertinent anomaly data (e.g., anomaly identity, amplitude, width, potential source, depth-to-target).

CORRECTIVE MEASURES

To be determined, as specified in the OE RDD.

DELIVERABLES

A Weekly QA Summary will be prepared and submitted to the OE Contractor, Granite, DTSC, and USACE presenting:

- Narrative summary of the audit of geophysical data.
- Documentation of data review including statistics, posting maps, image plots, and profiles including completion of the Daily Audit Checklist.
- Progressively updated table of grids completed, QA targets planted, and QA targets recovered.
- Progressively updated table of OE Contractor data deliverables.

Any data, maps, or images provided to the QA Contractor by the OE Contractor will be furnished to the USACE in a mutually to be agreed upon timely manner. Any reprocessed data, maps, or images produced by the QA Contractor, as part of their QA activities, will be furnished to the DTSC and USACE, as will any data resulting from QA resurveying of the investigation area.

COMPLETION REPORT

Upon completion of the OE remediation work at the Project Site, the QA Contractor will prepare a completion report presenting the results of the QA work; conclusions; and recommendations, if any. A State of California

licensed professional engineer/geologist/geophysicist familiar with the project data and results will sign the report. The report will be provided to the Granite Project Manager, DTSC, USACE and the OE Contractor.

DAILY AUDIT CHECKLIST

Geophysical, GPS, and data processing instrumentation and software Make, model, serial number recorded in field log.	
Field log Equipment serial number Dates Area covered Descriptions of features (e.g., potential noise sources) Field conditions (meteorologic, topographic, surface cover) Activities	
Field sketch map (updated daily)	
Pre-survey checklist completed each day	
Standardization in accordance with Project Work Plan/RDD	
Failed systems/components tagged and isolated Standard responses recomputed	
GPS units checked against reference each day Reference position (measured) recorded in daily log Variation from known position calculated	
Processing log details filenames, corrections, edits, filters/normalizations	
Data processing check form, processing log, and file management conventions established/implemented and followed	
Data processing software in accordance with the Project Work Plan/RDD	
Hard copy image/channel	
Correct coordinate system used (CSP NAD83)	
Instrument sampling rate (10 Hz)	
Survey speed yields ≤ 1-foot station spacings	
GPS update frequency correct (5 Hz) PDOP range acceptable (-)	
Survey coverage complete (survey lane overlap adequate)	
Symbol posting map of data stations prepared	
Tabulated target/anomaly list printed in ASCII format	
Signal-to-noise ration ≥ 1.5 for auto-picked targets	
Geographic features +/- 1.65 feet in geophysical data	
Data volume/channel varies < 1.0%	
Data density in accordance with Project Work Plan/RDD	
Data coverage ≥ 98%	
Project GIS updated daily	
Digital data delivered in IBM-compatible ASCII xyz format Preliminary processed data (conversion to ASCII) Spatially referenced (with temporal and spatial logs) Final processed (demoded, filtered, corrected for measurement drift)	
Field notes, updated maps, standardization documentation, digital data delivered in accordance with Project Work Plan/RDD schedule	

EcoMunition Ordnance and Explosives Services 3rd Party QA

ORDNANCE AND EXPLOSIVE (QA agent of DTSC)

QUALITY ASSURANCE MEMO

TO: Earth Tech	DATE:	TIME:
CONTRACT NUMBER: 52759	PROJECT LOCATION: Tourtelot Project Site Benicia California	
DO #:		

SUBJECT ITEMS(S) (Check all that apply):

- ☐ Work Plan
- ☐ Safety Violation
- ☐ Safety Comments
- ☐ Quality Assurance
- ☐ Other

DESCRIPTION:

☐ Prompt correction or compliance with contract specifications is requested.

OE Quality Assurance Rep

RECEIPT ACKNOWLEDGED:

Contractor's Representative

ACTION TAKEN:

(This is a modified version of CESPK form 948)

PROJECT SITE: TOURTELOT TCUP
CONTRACT DESCRIPTION: OE REMEDIATION PROJECT
AUDIT DATE:

CHECKPOINTS:

1. Review Scope of Work (DO/TO) & WP	REFERENCES	YES	NO	N/A	COMMENTS
a. Clearance Areas & Objectives Clearly Identified	Interim Guidance Document 98-10				
b. Check for Modifications/Changes & Up To Date					
c. OE RDD is current & all change pages posted					
d. Proper Depth of Clearance Identified					
e. Minimum Separation Distance (MSD) established & Based on the MPM	DOD 6055.9-STD/IGD 98-10, Chp. 8				
f. Corrective Action Standards Established					
g. Proper Target Ordnance Identified/Test Sources/Test Plot Established					
h. Most Probable Munitions (MPM) Identified					
i. Maps identifying the Proper MSD within the WP					
j. Standards for Turn-In of Recovered Inert OE & OE-Related Scrap	DOD 4160.21-M-1				
k. Inspection/Certification of AEDA	DOD 4160.21-M-1				
l. Explosive Safety Submission, Required on all OE Non-Time Critical Removal Actions	IGD 98-10, Chp. 10				
2. Documentation Requirements/Publications		YES	NO	N/A	COMMENTS
a. KO Approval Letter(s) for Work Plan/Mobilization of Project Personnel					
b. KO Contractor Qualifications, Approval Letter for All UXO Personnel Identified by Name & Position					
c. KO Approval Letter authorizing temporary substitution of personnel due to illness or absence					
d. Department of Defense Notice to Airmen (NOTAM) Local FAA	AR 95-10/AFR 11-208/OPNAVINST 3721-20B				
e. Certificate of Grounding, Lightning Protection (if Required)	DOD 6055.9-STD/ATF P 5400.7				
f. Approval Letter for Minimum Separation Distance,1 Frag in 600 sq. ft.	DID OT-005-04/Interim Guidance Document 98-10				
g. Explosive Safety Submission (ESS)					
h. Contract & All Modifications & Change Orders					
i. EM 385-1-1					
j. OE RDD & Site Safety & Health Plan					
k. First Aid & CPR Training Certificate (Minimum of 2 Personnel On-Site)	EM 385-1-1, Section 03.A.02				
l. Medical Qualification (Annual Physical Exam)	29 CFR 1910.120 (f)				
3. CEHNC QA Files Established	**OEQP09-15, Para. 9.0**	YES	NO	N/A	COMMENTS
a. Daily/Weekly QA Reports					
b. Approval Letter (NTP), Contractor Operations					
c. Weekly Contractor Reports (If Provided)					
d. CEHNC Form 948 (Blue Copy)					
4. Site-Specific Safety & Health Plan (SSHP)	**DID OT-005-06**	YES	NO	N/A	COMMENTS
a. Hazard Analysis & Risk Assessment for All Task & Equipment					
b. Training, General Site Workers HAZWOPER Qualified & Current 8-Hour Refresher	29 CFR 1910.120(e)				
c. Personnel Protective Equipment (PPE)	EM 385-1-1, 29 CFR 1910.120/134 & 132				
d. First Aid Equipment Shall be Immediately Available	EM 385-1-1				
e. Emergency Eye-washes/Showers Comply with ANSI Standards	ANSI Z-385.1				
f. Fire Extinguishers (Specific Type, Size and Location)	DID OT-005-06 & EM 385-1-1				
g. Ongoing Safety & Health Training Program					
h. Emergency Notification List Posted & Available	DID OT-005-06				
i. Emergency Routes/Maps Available & Issued to Each Team	DID OT-005-06				
j. Work Task Identified in Hazard Analysis	DID OT-005-06				
k. Appendix with all MSDS(s) for hazardous substances stored/used on-site	DID OT-005-06				
l. Adequate Site Control During Removal Operation (FWD/MSD)					

5. Facilities	EM 385-1-1	YES	NO	N/A	COMMENTS
a. Adequate Work Space & Facilities (Restrooms etc.)	Sections 2, 3 & 4				
b. Good Housekeeping (No Fire Hazards, Tripping Hazards etc.)	Sections 9 & 14				
c. Approved and Suitable Containers for Flammable & Toxic Materials	Section 9				
d. Approved/Adequate Explosive Storage Facilities	DOD 6055.9-STD/ATF P 5400.7 & Local Laws				
e. Fire/Emergency Exits Clear & Unbarred	Sections 1, 9, & 26				
f. Maximum Personnel Occupancy Limits Maintained (On-Site Office Trailers)					
6. Equipment	**Equipment Plan**	**YES**	**NO**	**N/A**	**COMMENTS**
a. Tools Appropriate and Serviceable					
b. Personnel Protective Equipment (PPE) Present, Serviceable & Utilized	EM 385-1-1, Section 5				
c. Equipment Calibrated (Last cal Date_____ Next cal Date_____)	Operators Manual				
d. Survey Equipment Inspected & Serviceable	Operators Manual				
e. Heavy Equipment Inspected & Serviceable	Operators Manual				
f. Two Separate Means of Communications, Radio(s)/Cell Phone, Land Line(s).	29 CFR 1910/1926.65/EM 385-1-1				
g. Appropriate Geophysical Equipment On-Hand, Serviceable & Identified in WP	DID OT-005-05/Operators Manual				
h. Copy of Manufacturers Instructions & Recommendations Maintained with all Hand and Power	Section 13, EM 385-1-1				
7. Transportation of Explosive Materials	**DOT, 49 CFR Parts 100 to 199; AR 385-64; EM 385-1-1 Sec 29**	**YES**	**NO**	**N/A**	**COMMENTS**
a. Motor Vehicle Inspections Performed In Good Repair)					
b. All Vehicles Transporting Explosives Shall Display All Placards, lettering, and/Numbering Required					
c. Compatibility Requirements Maintained					
d. Load Blocked and Braced					
e. First Aid Kit & Two 10 BC Rated Fire Extinguishers in Vehicle					
f. Vehicle shall Have Communication Capability					
g. Operators Transporting Explosive Shall Have Valid Drivers License					
h. Blasting Caps Shall be Separate and in Appropriate Container (Cap Box)					
i. No Flame-Producing Devices in Vehicle or on Persons					
8. Explosive Management Plan	**ATF 5400.7, DOD 6055.9-STD, DOT REG., AR 190-11, DID OT-005-03**	**YES**	**NO**	**N/A**	**COMMENTS**
a. Licenses/Permits (If Required)					
b. Proper Magazines (Type) being utilized					
c. Acquisition Plan (GFE or Purchased) & Description/Estimated Quality					
d. Explosive Compatibility Maintained) & Description/Estimated Quality	DOD 6055.9-STD/ATF P 5400.7/WP				
e. Each Explosive Item Identified in Equipment Plan (Not Required on FFP Task Orders)					
f. Initial Receipt Procedures & Documentation On-Site					
g. Fire Fighting Control Plan Established & Posted					
h. Proper Explosive Placards on each Magazine				N/A	
i. Proper Fire Division Symbol at Entrance to Storage Site					
j. Area Surrounding Magazine free of Rubbish, Brush, Dry Grass, Trees for a minimum of 25 foot. Control					
k. Storage Facilities & Physical Security of Explosives & Key Control					
l. Magazine Site meets IBD & Public Traffic Route Distance					
m. Commercial Explosives being Stored in DOD Facilities Require DOD HC/SCG Approval	DA PAM 385-64; AR 385-64			N/A	
n. Adequate Earth Cover used to meet IBD & Public Traffic Route Distances					
o. Explosives Specified within WP being used at Project Site					
p. NEW does not Exceed the Maximum NEW Established for Magazine					
q. Receipt Procedures Accounting for Each Item of Explosives/Documentation On-site					
r. Individuals Authorized to Receive, Issue and Transport Identified					
s. Certification by End User (In Writing)					
t. Reconciliation, Receipt Documents On-site					
u. Inventory Conducted Weekly @ Minimum				N/A	
v. Duplicate Magazine Data Cards (Magazine/Facility)	EM 385-1-1, Section 29.A.23(b)				

9. UXO Operational Plan	Work Plan	YES	NO	N/A	COMMENTS
a. Contractor Following Methodology Defined in OE RDD					
1. SUXOS Conducted Physical Check Prior to Sweep Operations					
2. Daily Safety Meeting Conducted by SSHO/SUXOS					
3. SUXOS On-Site Supervising Removal Operation					
4. Operational Condition Annotated in SUXOS Log Book					
5. UXO Supervisor (s)					
a. UXO Supervisor (s) Conducted Physical Check Prior to Sweep Operation					
b. Supervisor Ensures Public Barricades Established Prior to Sweep Operation					
c. Supervisor Ensures Sweep Operation being Conducted in Correct Grid					
d. Supervisor Conducted Pre-Operational Tail-Gate Safety Briefing					
e. Supervisor Ensures all Personnel are Wearing the Required PPE					
f. Supervisor Ensures Individual Sweep Lanes Established IAW WP					
g. Team using Correct Magnetometer & Model Specified in WP					
h. Instruments Checked Against Test Source Daily, Prior to Sweep Operations					
i. Results of Instrument Check, by Instrument Serial # annotated in Log Book					
j. Supervisor Ensures Individual Sweep Lanes Established IAW WP					
k. Supervisor Ensures Proper Sensitivity Setting Based On Check Sources					
l. Supervisor Ensures all Sub-Surface Anomalies Marked (If Applicable) & Investigated Properly					
m. All OE, Inert Items & Scrap Examined by at least TWO UXO Personnel and IAW OE RDD					
n. Supervisor Ensures all UXO's Clearly Marked IAW WP					
o. Non-OE Scrap being Collected IAW OE RDD					
p. Supervisor Ensures Non-OE Scrap being Collected (As Required)					
q. Results of Sweep Operation Recorded					
6. Operational Teams Operating IAW OE RDD					
10. Disposal Operations Planned On-Site	**Work Plan**	**YES**	**NO**	**N/A**	**COMMENTS**
a. Disposal Method IAW OE RDD					
b. Adequate Security For Disposal Operation					
c. Disposal Notification List Available					
d. All Necessary Notifications Made					
e. Movement of OE Items, IAW OE RDD					
f. Protective Measures/Tamping Being Used/Appropriate for OE Being Destroyed in Place					
g. Disposal Procedures IAW 60A-1-1-31/OE RDD					
1. Misfire Procedures Properly Performed (Electric)					
2. Misfire Procedures Properly Performed (Non-Electric)					
11. Location Survey & Mapping Plan	**DID OT-005-07**	**YES**	**NO**	**N/A**	**COMMENTS**
a. UXO Escort Provided					
b. Grid Stake, Locations Swept With Geophysical Equipment Prior to Driving Stakes					
c. Survey Notes Being Recorded					
12. Quality Control Plan	**DID OT-005-11**	**YES**	**NO**	**N/A**	**COMMENTS**
a. QC Operational/Audits Conducted IAW OE RDD					
b. QC Grid Sweep Pattern Adequate					
c. Quality Control Audits Recorded & Documentation Available for Inspection					
d. QC Training Conducted and Documented (Initial/On-Going)					
e. Quality Control Scrap inspection Conducted IAW OE RDD					
f. Results of QC Checks Being Recorded					

13. Transportation Plan	ATF 5400.7, DOD 6055.9-STD, DOT REG., AR 190-11, DID OT-005-03	YES	NO	N/A	COMMENTS
a. Pre-operational Checks of Vehicles Being Conducted					
b. All Operators Licensed For Vehicle					
c. Fire Fighting & First Aid Equipment On Board					
d. Cargo Properly Segregated/Blocked And Braced					
e. Proper DOT Placarding/Fire Fighting Symbols Used					
14. Vegetation Removal	**Interim Guidance Doc. 98-10 & WP/SSHP**	**YES**	**NO**	**N/A**	**COMMENTS**
a. Vegetation Removal & Localized, if Required					
b. Equipment Operated To Prevent Impact With Possible Surface OE					
c. Cutting Does Not Present Implement Hazard					
d. UXO Personnel Monitoring Cutting Operation					
e. OE Discovered Marked/Handled Appropriately					

SIGNATURE: _____

Comments: _____

APPENDIX O

Standard Operating Procedure
Third-Party Quality Assurance

STANDARD OPERATING PROCEDURE
3RD PARTY QUALITY ASSURANCE

GENERAL

The Project Quality Assurance (QA) shall entail ordnance and explosives oversight and three geophysical related tasks: (1) an audit of the geophysical survey data collected; (2) detection performance quality control (QC) verification of 25 percent of the point cleared grids; and (3) performance of a resurvey of at least five (5) percent of the investigation area. These activities will include a daily audit of tasks performed by the OE Contractor.

ORDNANCE AND EXPLOSIVES OVERSIGHT

The QA Contractor will be responsible for oversight of all OE operations to be implemented by the Remediation Contractor. The QA Contractor will evaluate conformance to the OE plans by performing audits, surveillance, and reviews of work processes and acquired data using the OE QA On-Site Check List provided as Enclosure 1. The QA Contractor will report to DTSC and has the authority to require corrective actions and stop work, as needed, to ensure compliance with OE plans.

- Review and document the Contractor's daily activities for compliance with the approved plans for the site.
- Conduct daily inspections and document of field activities to ensure work is conducted in accordance with (IAW) OE RDD.
- Coordinate any changes required in MSDs and/or the Explosive Safety Submission.
- Verify that any changes to an MSD are done IAW Appendix C of the OE RDD.
- Monitor daily safety routines and document conformance to the Appendix F of the OE RDD.
- Participate in daily safety briefings during all phases of the project.
- Observe all field operations (monitor removal actions).
- Oversee, by daily inspection, the OE contractor to verify all removal actions are conducted IAW the OE RDD.
- Review field changes with site/project team, DTSC, and USACE.
- Attend Preparatory Meetings.
- Verify MSDs are appropriate for all Sectors.
- Place Blind Seeds in test plot as directed by DTSC and USACE .
- Review all 'Safe to Move' determinations.
- Observe demolition operations to include Donovan Chamber, ensure all demolition operations are conducting IAW the OE RDD.
- Place targets for 'blind' seeding of grids as directed by DTSC and USACE.
- Conduct a 10% QA Search Effectiveness audit of all grids submitted by the OE Contractor for audit using a metals detector and submit 948 report for each grid
- Analyze point clearance data and participate in decision to go to area wide clearance.
- Monitor Project Conformance Audit Schedule (Appendix H of the OE RDD).
- Review dig selection process with Geophysical QA.
- Provide copy of daily QA Report to USACE OE Safety Specialist and DTSC.
- Provide daily Team assignment roster at the start of each work day to USACE Safety Specialist.

The QA Contractor will adhere to the safety and health requirements contained in the OE plans. During all field operations, the QA Contractor will perform UXO avoidance procedures. The QA Contractor will not conduct intrusive operations other than the burial of QA targets. The specific OE safety and health requirements that will be monitored by the QA Contractor are contained in the following regulations:

- EP 385-1-95a, Basic Safety Concepts and Considerations for Ordnance and Explosive Operations.
- EP 75-1-2, UXO Support during HTRW and Construction Activities.
- EM 1110-1-4009, Ordnance and Explosives Response.
- EM 385-1-1, U.S. Army Corps of Engineers Safety and Health Manual.
- DoD 6055.9 STD DoD Ammunition and Explosives Safety Standards
- ATF 5400.7 Federal Explosives Law and Regulations
- EP 1110-1-18 Ordnance and Explosives Response
- DA Pam 385-64 Ammunition and Explosives Safety Standards
- Applicable 60 Series Publications
- ER 385-1-95 Safety and Health Requirements for Ordnance and Explosives Response Actions
- AR 385-64 US Army Explosives Safety Program
- Applicable USACE HNC Guidance documents.

GEOPHYSICAL DATA COLLECTION AND PROCESSING

The QA contractor will perform an audit review of the geophysical data collected for each sector. This audit will initially comprise an inspection and review of 100 percent of the collected data. Following review and acceptance of the data by the QA Contractor, the California Department of Toxic Substance Control (DTSC) and the USACE, the QA audit will be reduced to 50 percent of the data, to be followed by further step reductions, as recommended by the QA Contractor and approved by the DTSC. These inspections will include checks of instrument standardization documentation, completeness of the mapping coverage, and the representativeness of the anomaly sources. Additionally, the QA contractor will re-process at least 10% of the geophysical data using the *Geosoft Mapping and Processing System and OE Target Analysis.*

The QA evaluation will include:

- Review of OE Contractor daily field QA documentation (e.g., maps, field notes)
- Review of standardization results (instrument precision)
- Derivation of data statistics and measurement coordinates (location accuracy)
- Posting of data stations for each segment (survey/coverage completeness)
- Generation of contour/image/profile plots (representativeness/reasonableness)
- Comparison of field anomaly map, digital data image, and OE sampling results for each area investigated (representativeness). This review may include assessment of previously generated geophysical data.
- Verifying geophysical data is generated and delivered in accordance with the agreed upon schedule and that the OE Contractor is maintaining the quality control procedures and schedules for data acquisition, processing, and interpretation specified in the Tourtelot Project Site Ordnance and Explosives Remedial Design Document (OERDD).

QA processing will include production of representative profiles. The profile images will be compared to the data processed imaging of the OE contractor over the same survey area to determine correlation between identified potential OE anomalies. The compared anomaly lists will be tabulated and presented to the Granite Project Coordinator, DTSC, USACE, and the OE contractor.

Geophysical Data Evaluation

The QA Contractor will review the field data daily to identify unusable or incomplete data delivered for any transect. Field data will be reviewed to ensure complete coverage, measurement precision, representativeness, and geophysical reasonableness of the survey results. The QA Contractor will forward to the DTSC and USACE copies of all data, maps, and images received from the OE Contractor in accordance with the same delivery schedule as is delivered by the OE Contractor.

The QA contractor will ensure that a daily log and a field sketch map of mapped survey grids and paths are made as the geophysical data collection progresses. All activities related to geophysical data collection are to be documented in the daily log. Field maps will note date/time of the survey, area covered, and the location and description of potential noise sources that could affect interpretations.

Daily logs will record:

- Morning pre-survey checks of instrument and batteries
- Safety and planning briefing
- Identification of traverse segment(s) to be mapped
- Equipment set-up
- Definition data file names
- Initialization of data logger(s) to record geophysical response
- Performance of instrument standardization
- Any areas not surveyed due to site specific conditions
- Delivery of digital survey data to the Site Manager (including, raw, basic processed, or final processed data).

An independent review and verification of the geophysical data will be performed by the QA contractor. Data will be audited by processing data from randomly selected grids using *Geosoft Mapping and Processing System and UXO Target Analysis*. QA processing of digital data will include production of representative profiles. The raw data from the data loggers will be used to create image plots; the data will not be filtered unless background noise levels are excessive (this will be determined during the first week of the field effort). The images will be used as a QA tool to compare visually discriminated locations with those anomaly locations identified by the automated (digital) target picking routines used to generate the anomaly "dig" lists.

The basic processed and final processed data will undergo the same review (data analysis and generation of image plots). The image maps provided by the OE Contractor must have areas not surveyed, due to site specific conditions (vegetation, terrain, or other physical obstacles), clearly delineated.

The basic processed and final processed data files will be checked to ensure that each file has a header that contains, at the least, the following information:

- Geophysical Subcontractor
- Sensor – name, model of instrument, serial numbers
- Start date for acquisition/processing of data in file
- End date – date data acquisition/processing complete
- Survey line spacing
- Data density along traverse
- Survey block of grids encompassed by data in file
- Name of raw data file(s) for data in file
- Begin point (easting) for data in file
- Begin point (northing) for data in file
- Number of data columns in file, followed by description of each data column
- Column for each data channel (Z1, Z2, . . . Zn)
- Comments – site/grid specific comments
- Corrections – describe corrections/edits, if any, applied to data during processing. Cross-reference separate data processing files as required.

The field review will ensure that precise measurements of the geophysical response were obtained by verifying that instrument performance during standardization fell within the established ±10 percent acceptance range. Daily standardization measurements and results are to be completely documented in the daily field log. The daily logs will be reviewed to ensure proper implementation of the quality controls.

The State Plane coordinates recorded for each transect will be compared with a master listing to ensure that the sampling data are accurately located within the study area. The field logs will also be reviewed each day to verify that data were collected following a continuous progression along the transects. If the survey progression was interrupted for a particular segment because of terrain or other considerations, the causes of the deviation and the actual mode of progression should be fully described in the daily log notes.

The field review will ensure that the transect investigation was complete by verifying that the data volume for each receiver array is comparable (±1 percent) and that the spatial data density (measurements per unit distance) is representative of the mapping effort described in the daily log. Field notes will be compared to the downloaded digital file data to assure correspondence between transects searched and transects recorded.

Anomaly Discrimination

The QA contractor will review anomaly picks to ensure responses with characteristics that could be representative of targets of interest (e.g., OE projectiles) are discriminated in the data. The anomaly discrimination process will not eliminate any anomalies from the investigation other than those that are clearly not associated with OE, such as long linear trends, obvious geologic features, or responses that are demonstrably (e.g., through field notes) caused by surface artifacts, based on the available geophysical, visual, and historical data. The data review will ensure that anomalies of concern (those with a signal-to-noise ratio (S/N) sufficient to discriminate target responses in the data) are identified. Minimally, the S/N should be at least 1.5 times greater than the background threshold level.
The hard copy and digital "Dig-Sheets" provided by the OE Contractor will be reviewed for inclusion of the following:

- Project Site
- Date data acquired
- Date final data processed
- Responsible Geophysicist
- Sector/Area
- Grid Number/Transect
- Anomaly Number
- State Plane Coordinate Location (northing and easting)
- Anomaly Location Reacquired and Marked
- Estimated Depth to Top of Item
- Actual Depth to Top of Item
- Maximum Amplitude of Original Anomaly
- Maximum Amplitude of Reacquired Anomaly Location

Performance Criteria.

Locational Accuracy. **The QA Contractor will verify that** survey lane segments correspond to the areas actually investigated by the geophysical teams. Further, the data acquired along each survey lane will be checked to verify they are accurately located relative to State Plane coordinates in order to assure proper characterization of the sectors.

The State Plane coordinates recorded for each transect will be compared with a master listing to ensure that the sampling data are accurately located within the study area. The field logs will also be reviewed each day to verify that data were collected following a continuous progression along the transects. If the survey progression was interrupted for a particular segment because of terrain or other considerations, the causes of the deviation and the actual mode of progression should be fully described in the daily log notes and in the header of that particular grid survey file. Plots of the survey progress will be updated each day and transferred to a site map to aid in tracking the actual search areas.

Instrument Precision. **The QA Contractor will verify that the** proper operation and function of the geophysical survey system is checked and documented in the field log each day by a standardization process prior to the beginning and at the end of each geophysical survey episode (defined as before survey segment begins and prior to turning the equipment off at the end of any survey segment). Instrument standardization responses will be checked to verify that the responses vary by no more than ±10 percent of standard response obtained for each deployed geophysical system. Acceptance range will be specified at ±10 percent of the standard response (calculated mean residual anomaly). Field log entries will be inspected to ensure instrument performance meets the standardization criterion. The standardization data recorded by the geophysical survey team will be evaluated to ensure that the system meets the specified survey requirements.

Completeness. **The QA Contractor will verify that the** data were collected in such a manner that a data mesh specific to the targets of concern could be generated for the transect survey. Field logs will be reviewed, and the QA Contractor will post digital data to a segment track map to determine if there are any missing data stations not accounted for in the field notes.
The field review will ensure that the transect investigation was complete by verifying that the data volume for each receiver array is comparable (±1 percent) and that the spatial data density (measurements per unit distance both longitudinally and transverse to the survey line) is representative of the mapping effort described in the

daily log and as specified in the OE RDD. **The QA Contractor will verify that the** Survey data was captured [illegible]h that 98 percent of measurements at increments of 1 foot or less along each transect were recorded. Field notes will be compared to the downloaded digital file data to assure correspondence between transects searched and transects recorded.

Geophysical Reasonableness. The QA Contractor will review the recorded geophysical responses to verify that they reflect the physical properties of conductive materials in the near-surface. Data will be inspected to ensure anomaly responses caused by small, finitely bounded concentrations of conductive soils or minerals are differentiable in the recorded data. Noise levels in the data will be analyzed to ensure that they are sufficiently low to allow adequate signal-to-noise differentiation of pertinent anomalies, based on static and translational noise tests conducted during the equipment field tests.

Geophysical Data Management. The QA Contractor will review and ensure that the geophysical data are properly acquired, processed, interpreted, and stored in a comprehensive manner. This includes verifying the completeness and accuracy of any informational databases related to the geophysical operations. Along with the acquisition, processing, and interpretation databases, the QA Contractor needs to ensure that the OE Contractor is tracking deliverables of raw, basic processed, final processed, and all quality control data (geophysical, positional, and OE investigation), and that they are tracking their own quality assurance evaluations.

QUALITY ASSURANCE CONFIRMATION RESURVEYING

The QA Contractor will also resurvey at least five percent (5%) of the investigated area with the same or similar [illegible]physical instrumentation to ensure that the OE Contractor-acquired data are representative of the site.

DETECTION PERFORMANCE

Blind Seeding

Performance Objectives for this remediation require 100 percent detection of all seeded QC targets. The QC targets will be planted prior to geophysical mapping of the individual sectors at the project site. The QA Contractor will seed each 100-foot by 100-foot grind in Sector 10B and 25 percent of the 100-foot by 100-foot grids in the remainder of the Project Site with one (1) or more inert projectiles. Seeded targets will be placed in a horizontal plane at or above the maximum reliable depth of detection (MRDD) for a 37mm (or 60mm, as appropriate to each sector of the site) projectile, as determined at an equipment test plot on the Tourtelot Project Site.
Grids to be seeded within each sector will be randomly selected using a random number generator. The location of each seeded target will also be randomly generated using grid northings and eastings with a table of generated random grid coordinates. For each seeded QC target, the position (in CSP grid feet, NAD83) +/- 4 inches, the depth (+/- 0.10-inch) and the orientation (axial bearing +/- 5 degrees) will be determined and recorded in an electronic database.

OE avoidance procedures will be followed when the targets are planted. The QA Contractor will record and report the target position using a DGPS or RTK GPS with better than 4-inch horizontal accuracy.

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The QA Contractor will be given the coordinate location and depth of each QC target discovered by the OE Contractor during the point clearance OE removal. The OE Contractor will inform the QA Contractor when the point clearance of each grid is complete. The QA Contractor will compare the list of discovered QC targets with the QA database. Failure to find any QC targets in a given grid at or above the MRDD constitutes a detection failure for the particular grid. Such failures will be reported to the Granite Project Coordinator, DTSC, USACE, and the OE Contractor.

Metal Detector Checks

Prior to OE escort or surface activities, a check bed will be established by burying three (3) steel simulators approximating the size and nominal equivalence of a 37mm HE projectile to a depth of 12 inches bgs. Metal detectors are checked against these sources to ensure they are operational and capable of detecting targets of concern.

The QA Contractor will verify that the daily logbooks document that each deployed metal detector was checked daily against a known metallic anomaly source. To ensure that instruments remain operational during field operation, all instruments will be checked by the Senior UXO Supervisor against a surface anomaly (i.e., keys, watch, leatherman). This check will be recorded in the logbooks and verified by the QA Contractor.

EP 1110-1-18, Ordnance and Explosives Response, ER 1110-1-12, Quality Management, ER 1110-1-8158

RECORDS MANAGEMENT

The QA Contractor will ensure that all daily notes are recorded in bound field notebooks, digitally captured data copied to archive disks, and that all data files are accompanied by Microsoft Word documents detailing file content, file naming, and data processing performed on the field data.

QUALITY ASSURANCE SUMMARY

The QC results of the OE clearance will be tracked on a master spreadsheet that will tabulate survey area identification, coordinates, and date surveyed. A **Weekly QA Summary** will be prepared and submitted to Granite's Project Coordinator, DTSC, USACE, and the OE Contractor. The summary will include the items delineated in the following subsections.

Precision

A mean deviation from the standard response will be calculated for each instrument used. This will be reported in a progressively updated table.

Accuracy

Any discrepancies in positional or locational accuracy of the data noted during the field review will be described, including steps taken to correct or resolve any such QC issues.

Completeness

e percentage of coverage of each investigated segment will be tabulated. Significant lack of coverage (> 2 percent missed) will be flagged and annotated with the steps to be taken to resolve the missed coverage. Unavoidable obstacles will have been mapped on the field sketches and should result in direct correspondence with missing data. The steps that are presented in Section 4 of the OE RDD will be followed if data shortages are detected.

Reasonableness

Any variations or results not compatible with prior results or expectations will be reviewed with the OE Contractor geophysicist to determine causative features that may be present. These field contacts will be summarized and included in the weekly QA summary report.

Representativeness

A table will be developed and progressively updated that presents pertinent anomaly data (e.g., anomaly identity, amplitude, width, potential source, depth-to-target).

CORRECTIVE MEASURES

To be determined, as specified in the OE RDD.

DELIVERABLES

A Weekly QA Summary will be prepared and submitted to the OE Contractor, Granite, DTSC, and USACE presenting:

- Narrative summary of the audit of geophysical data.
- Documentation of data review including statistics, posting maps, image plots, and profiles including completion of the Daily Audit Checklist.
- Progressively updated table of grids completed, QA targets planted, and QC targets recovered.
- Progressively updated table of OE Contractor data deliverables.

Any data, maps, or images provided to the QA Contractor by the OE Contractor will be furnished to the USACE in a mutually to be agreed upon timely manner. Any reprocessed data, maps, or images produced by the QA Contractor, as part of their QA activities, will be furnished to the DTSC and USACE, as will any data resulting from QA resurveying of the investigation area.

COMPLETION REPORT

Upon completion of the OE remediation work at the Project Site, the QA Contractor will prepare a completion report presenting the results of the QA work; conclusions; and recommendations, if any. A State of California licensed professional engineer/geologist/geophysicist familiar with the project data and results will sign the report. The report will be provided to the Granite Project Manager, DTSC, USACE and the OE Contractor.

DAILY AUDIT CHECKLIST

Geophysical, GPS, and data processing instrumentation and software Make, model, serial number recorded in field log.	
Field log Equipment serial number Dates Area covered Descriptions of features (e.g., potential noise sources) Field conditions (meteorologic, topographic, surface cover) Activities	
Field sketch map (updated daily)	
Pre-survey checklist completed each day	
Standardization in accordance with Project Work Plan/RDD	
Failed systems/components tagged and isolated Standard responses recomputed	
GPS units checked against reference each day Reference position (measured) recorded in daily log Variation from known position calculated	
Processing log details filenames, corrections, edits, filters/normalizations	
Data processing check form, processing log, and file management conventions established/implemented and followed	
Data processing software in accordance with the Project Work Plan/RDD	
Hard copy image/channel	
Correct coordinate system used (CSP NAD83)	
Instrument sampling rate (10 Hz)	
Survey speed yields ≤ 1-foot station spacings	
GPS update frequency correct (5 Hz) PDOP range acceptable (-)	
Survey coverage complete (survey lane overlap adequate)	
Symbol posting map of data stations prepared	
Tabulated target/anomaly list printed in ASCII format	
Signal-to-noise ration ≥ 1.5 for auto-picked targets	
Geographic features +/- 1.65 feet in geophysical data	
Data volume/channel varies < 1.0%	
Data density in accordance with Project Work Plan/RDD	
Data coverage ≥ 98%	
Project GIS updated daily	
Digital data delivered in IBM-compatible ASCII xyz format Preliminary processed data (conversion to ASCII) Spatially referenced (with temporal and spatial logs) Final processed (demoded, filtered, corrected for measurement drift)	
Field notes, updated maps, standardization documentation, digital data delivered in accordance with Project Work Plan/RDD schedule	

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