Fort Ord known and suspected Munitions and Pesticide Chemicals used in Training Areas

How can the extent of contamination in training areas be known if the cleanup program is not looking for all the potential chemicals?

Table 1: List of munitions chemicals compiled from 1994 Site 39 Remedial Investigation
Note: very few are being looked for in training areas.

Table 2: List of munitions chemicals compiled from 2003 Sampling and Analysis Plan
Note: very few are being looked for in training areas.

Table 3: List of munitions chemicals Military Explosives (Chemistry) 30 September 1984
Note: many of these munitions chemicals are not included in Tables 1 & 2

Table 4: List of munitions chemicals found in practice and pyrotechnic munitions
Note: many of these munitions chemicals are not included in Tables 1 & 2

Table 5: List of 23 pyrotechnic chemicals also used as Pesticides
Note: may explain why some training areas appear to be devoid of life
(very few bugs, birds, ground squirrels, etc.)

Table 6: List of 48 pesticides used at Fort Ord
Note: none of these chemicals have been looked for in training areas.

Table 7: Munitions Chemicals looked for in transferred training areas FORA ESCA RP parcels
Note: in training areas, very few and in some sites **no** munitions chemicals have been looked for. **No** pesticide chemicals have been looked for.

Map 1: Pesticide sampling locations
Note: This map generated from Fort Ord RI/FS 1995, VOL II - Remedial Investigation, Basewide Background Soil Investigation 1995; BW-1283E
This is **the only specific sampling for pesticides in training areas** known

Map 2: Site 39; Seaside Groundwater Basin
Note: This aquifer is the potable water supply for much of the Monterey Peninsula

Map 3: Historical Areas (HA) Sites
Note: Fort Ord training areas

FOCAG cleanup comment letters can be viewed in the Fort Ord Administrative Record by going to FortOrdCleanup.com

Table 1: Munitions Chemicals identified by the Fort Ord Superfund cleanup; 1994 RI/FS BW-1283K Tables

Phenol
Bis(2-chloroethyl) ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl alcohol
1,2-Dichlorobenzene
2-Methylphenol
4-Methylphenol
n-Nitrosodipropylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Benzoic acid
Bis(2-chloroethox)methane
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-methylphenol
2-Methlnaphthalene
Hexachorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethl phthalate
Acenaphthylene
2,6-Dinitrotoluene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
Diethyl phthalate
4-Chlorophenyl phenylether
Fluorene
4-Nitroaniline
4,6-Dinitro-2-methyl phenol
n-Nitrosodiphenylamine
4-Bromophenylphenylether
Hexachlorobenzene

Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butlphthalate
Fluoranthene
Pyrene
Butylbenzylphthalate
3,3-Dichlorobenzidine
Benzo(a)anthracene
Chrysene
Bis(2-ethlhexyl)phthalate
Di-n-octyIphthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(l,2,3-cd)pyrene
Dibenzo(a,h)antkracene
Benzo(ghi)perylene
Bis(2-chloroisopropyl)ether
TPH-Diesel
TPH-Extractable Unknown Hydrocarbon
TPH-Gasoline
TPH-Purgeable Unknown Hydrocarbon
Benzene
Ethylbenzene
Toluene
Xylenes
HMX
RDX
1,3,5-Trinitrobenzene
1,3-Dinitrobenzene
Tetryl
Nitrobenzene
2,4,6-Trinitrotoluene
2,4-Dinitrotoluene
2,6-Dinitrotoluene
o-NitroToluene
m-NitroToluene
p-ilitrotoluene
2-Amino-dinitrotoluene
4-Amino-dinitrotoluene
Nitroalvcerin
Picri;-hcid
Nitroguanidine
PETN

Table 2: Munitions Chemicals identified by the Superfund cleanup: 2003 Sampling and Analysis Plan, Revision 0; Fort Ord, California; BW-2214D

Gasoline (C -C)	8006-61-9
4-Bromofluorobenzene	460-00-4
Diesel (C -C)	68334-30-5
Motor Oil (C -C)	ADR-02-001
ortho-terphenyl	84-15-1
Acetone	67-64-1
Benzene	71-43-2
Bromobenzene	108-86-1
Bromochloromethane	74-97-5
Bromodichloromethane	75-27-4
Bromoform	75-25-2
Bromomethane	74-83-9
2-Butanone	78-93-3
n-Butylbenzene	104-51-8
sec-Butylbenzene	135-98-8
tert-Butylbenzene	98-06-6
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroethane	75-00-3
2-Chloroethyl vinyl ether	110-75-8
Chloroform	67-66-3
Chloromethane	74-87-3
2-Chlorotoluene	95-49-8
4-Chlorotoluene	106-43-4
Dibromochloromethane	124-48-1
1,2-Dibromo-3-chloropropane	96-12-8
1,2-Dibromoethane	106-93-4
Dibromomethane	74-95-3
1,2-Dichlorobenzene	95-50-1
1,3-Dichlorobenzene	541-73-1
1,4-Dichlorobenzene	106-46-7
Dichlorodifluoromethane	75-71-8
1,1-Dichloroethane	75-34-3
1,2-Dichloroethane	107-06-2
1,1-Dichloroethene	75-35-4
cis-1,2-Dichloroethene	156-59-2
trans-1,2-Dichloroethene	156-60-5
1,2-Dichloropropane	78-87-5
1,3-Dichloropropane	142-28-9
2,2-Dichloropropane	594-20-7
1,1-Dichloropropene	563-58-6
cis-1,3-Dichloropropene	10061-01-5
trans-1,3-Dichloropropene	10061-02-6
Ethylbenzene	100-41-4

Hexachlorobutadiene	87-68-3
2-Hexanone	591-78-6
Isopropylbenzene	98-82-8
p-Isopropyltoluene	99-87-6
Methyl tert-butyl ether	1634-04-4
Methylene chloride	75-09-2
4-Methyl-2-pentanone	108-10-1
n-Propylbenzene	103-65-1
Styrene	100-42-5
1,1,1,2-Tetrachloroethane	630-20-6
1,1,2,2-Tetrachloroethane	79-34-5
Tetrachloroethene	127-18-4
Toluene	108-88-3 75-125
1,2,3-Trichlorobenzene	87-61-6
1,2,4-Trichlorobenzene	120-82-1
1,1,1-Trichloroethane	71-55-6
1,1,2-Trichloroethane	79-00-5
Trichloroethene	79-01-6
Trichlorofluoromethane	75-69-4
1,2,3-Trichloropropane	96-18-4
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethylbenzene	08-67-8
Vinyl acetate	108-05-4
Vinyl chloride	75-01-4
m,p-Xylene	1330-20-7
o-Xylene	95-47-6
4-Bromofluorobenzene	1868-53-7
Dibromofluoromethane	460-00-4
1,2-Dichloroethane-d4	17060-07-0
Toluene-d8	2037-26-5
Acenaphthene	83-32-9
Acenaphthylene	208-96-8
Anthracene	120-12-7
Benzoic acid	65-85-0
Benzo[a]anthracene	56-55-3
Benzo[b]fluoranthene	205-99-2
Benzo[k]fluoranthene	207-08-9
Benzo[g,h,i]perylene	191-24-2
Benzo[a]pyrene	50-32-8
Benzyl alcohol	100-51-6
Bis(2-chloroethoxy)methane	111-91-1
Bis(2-chloroethyl)ether	111-44-4
Bis(2-chloroisopropyl)ether	108-60-1
Bis(2-ethylhexyl)phthalate	117-81-7
4-Bromophenyl phenyl ether	101-55-3
Butylbenzylphthalate	85-68-7
Carbazole	86-74-8

4-Chloroaniline	106-47-8
4-Chloro-3-methylphenol	35421-08-0
2-Chloronaphthalene	91-58-7
2-Chlorophenol	95-57-8
4-Chlorophenyl phenyl ether	7005-72-3
Chrysene	218-01-9
Dibenzo(a,h)anthracene	53-70-3
3,3'-Dichlorobenzidine	91-94-1
Dibenzofuran	132-64-9
1,2-Dichlorobenzene	95-50-1
1,3-Dichlorobenzene	541-73-1
1,4-Dichlorobenzene	106-46-7
2,4-Dichlorophenol	120-83-2
Diethylphthalate	84-66-2
2,4-Dimethylphenol	105-67-9
Dimethyl phthalate	131-11-3
Di-n-butylphthalate	84-74-3
4,6-Dinitro-2-methylphenol	534-52-1
2,4-Dinitrophenol	51-28-5
2,4-Dinitrotoluene	121-14-2
2,6-Dinitrotoluene	606-20-2
Di-n-octyl phthalate	117-84-0
Fluoroanthene	206-44-0
Fluorene	86-73-7
Hexachlorobenzene	118-74-1
Hexachlorobutadiene	87-68-3
Hexachlorocyclopentadiene	77-47-4
Hexachloroethane	67-72-1
Indeno(1,2,3-cd)pyrene	193-39-5
Isophorone	78-59-1
2-Methylnaphthalene	91-57-6
2-Methylphenol	95-48-7
3-Methylphenol	108-39-4
4-Methylphenol	106-44-5
Naphthalene	91-20-3
2-Nitroaniline	88-74-4
3-Nitroaniline	99-09-2
4-Nitroaniline	100-01-6
Nitrobenzene	98-95-3
2-Nitrophenol	88-75-5
4-Nitrophenol	100-02-7
N-Nitroso-di-n-butylamine	924-16-3
N-Nitrosodiethenolamine	1116-54-7
N-Nitrosodiphenylamine	86-30-6
N-Nitroso-di-n-propylamine	621-64-7
Pentachlorophenol	87-86-5
Phenanthrene	85-01-8
Phenol	108-95-2

Pyrene	129-00-0
Pyridine	110-86-1
1,2,4-Trichlorobenzene	120-82-1
2,4,5-Trichlorophenol	95-95-4
2,4,6-Trichlorophenol	88-06-2
2,4,6-Tribromophenol	118-79-6
2-Fluorobiphenyl	321-60-8
2-Fluorophenol	367-12-4
Nitrobenzene-d5	20810-28-0
Phenol-d6	4165-62-2
Terphenyl-d14	98904-43-9
HMX	2691-41-0
sym-Trinitrobenzene	99-35-4
RDX	121-82-4
1,3-Dinitrobenzene	99-65-0
Nitrobenzene	98-95-3
2,4,6-Trinitrotoluene	118-96-7
Tetryl	479-45-8
2,4-Dinitrotoluene	121-14-2
2,6-Dinitrotoluene	606-20-2
2-Am-DNT	35572-78-2
4-Am-DNT	1946-51-0
2-Nitrotoluene	88-72-2
3-Nitrotoluene	99-08-1
4-Nitrotoluene	99-99-0
Nitroglycerin	55-63-0
1,4-Dinitrobenzene	100-25-4
Aluminum	7429-90-5
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Calcium	7440-70-2
Chromium	7440-47-3
Cobalt	7440-48-4
Copper	7440-50-8
Iron	7439-89-6
Lead	7439-92-1
Magnesium	7439-95-4
Manganese	7439-96-5
Molybdenum	7439-98-7
Nickel	7440-02-0
Potassium	7440-09-7
Selenium	7782-49-2
Silver	7440-22-4
Sodium	7440-23-5
Strontium	7440-24-6

Thallium	1314-32-5
Titanium	7440-32-6
Vanadium	7440-62-2
Zinc	7440-66-6
Mercury	7439-97-6
Perchlorate	14797-73-0

Table 3. Munitions Chemical Compositions

Explosives, Propellants, Pyrotechnics
Military Explosives (Chemistry) 30 September 1984

Explosives

Chapters 7 & 8

Lead Azide: $Pb(N_3)_2$, is a salt of hydrazoic acid, HN_3. The compound is white, has a nitrogen content of 28.86 percent and a molecular weight of 291.26. At the melting point, 245°C to 250°C, decomposition into lead and nitrogen gas occurs. The pure compound has two crystal modifications: an orthorhombic form and a monoclinic form. The orthorhombic form, which is also called the alpha form, has a density of 4.68 grams per cubic centimeter and unit cell dimensions of a = 11.31 Angstroms, b = 16.25 Angstroms, and c = 6.63 Angstroms. The monoclinic form, which is also called the beta form, has a density of 4.87 grams per cubic centimeter and unit cell dimensions of a = 18.49 Angstroms, b = 8.84 Angstroms, and c =5.12 Angstroms. The compound is usually prepared as colorless, needlelike crystals.

Other Lead Azide Types:

Dextrinated Lead Azide (DLA)
Service Lead Azide (SLA)
Colloidal Lead Azide (CLA)
Polyvinylalcohol Lead Azide (PVA-LA)
RD-1333 lead azide
Dextrinated Colloidal Lead Azide (DCLA)

Mercury Fulminate $Hg(ONC)_2$, is a salt of fulminic or paracyanic acid. The acid undergoes polymerization very rapidly in both aqueous and ethereal solutions, and so cannot be isolated. The structure of fulminic acid, and thus the salts of this acid, is undetermined. Mercury fulminate has an oxygen balance to CO_2 of-17 percent, an oxygen balance to CO of -5.5 percent, a nitrogen content of 9.85 percent, and a molecular weight of 284.65. When mercury fulminate is crystallized from water, a hydrate, Hg(ON: C).1/2 H_2O, is formed that has a nitrogen content of 9.55 percent and a molecular weight of 293.64. The anhydrous form, which is crystallized from alcohol, is white when pure but normal manufacturing yields a gray product of only 98 to 99 percent purity. The crystals formed are octahedral but are usually truncated. Only the smaller crystals are fully developed. The crystal density is 4.43 grams per cubic centimeter.

Diazodinitrophenol (DDNP) This explosive is also known as 4,5-dinitrobenzene-2-diazo-1-oxide, dinol, diazol and may be referred to as DADNP. The compound is a greenish yellow to brown solid with tabular crystals. DDNP has a crystal density of 1.63 to 1.65 grams per cubic centimeter at 25°C and a molecular weight of 210.108. DDNP is not dead pressed even at a pressure of 896,350 kilopascals (130,000 pounds per square inch).

Lead Styphnate Two forms of lead styphnate are used as primary explosives: basic and normal. Basic lead styphnate has a nitrogen content of six percent and a molecular weight of 705.53.

The compound has two crystal forms: yellow needles with a density of 3.878 grams per cubic centimeter and red prisms with a density of 4.059 grams per cubic centimeter. The apparent density is 1.4 to 1.6 grams per cubic centimeter. Normal lead styphnate has a nitrogen content of nine percent and the monohydrate has a molecular weight of 468.38.

Tetracene is also known as guanyldiazoguanyl tetrazene and 4-guanyl-1 -(nitrosoaminoguanyl)-1tetrazene. The compound is a colorless to pale yellow, fluffy material with needle crystals, an oxygen balance to CO2 of-57.6 percent, an oxygen balance to CO of-43 percent, a nitrogen content of 74.4 percent, and a molecular weight of 188.15. Tetracene forms a hydrate with three molecules of water. The melting point of the pure compound is between 140°C and 160°C accompanied by decomposition and explosion. The apparent density is only 0.45 grams per cubic centimeter. When compressed at 20,685 kilopascals (3,000 pounds per square inch), the density is 1.05 grams per cubic centimeter. The crystal density is 1.7 grams per cubic centimeter. The compound can be easily dead pressed. Tetracene is practically insoluble in water and ethanol and so can be stored wet with water or a mixture of water and ethanol. The compound is also insoluble in ether, benzene, acetone, carbon tetrachloride, and ethylene dichloride. Tetracene is soluble in dilute nitric acid or strong hydrochloric acid. In a solution with hydrochloric acid, the hydrochloride is precipitated by the addition of ether. Tetracene may then be recovered by treatment with sodium acetate or ammonium hydroxide. The heat of formation is 270 calories per gram and the heat of detonation is 658

Potassium Dinitrobenzofuroxane (KDNBF) is a red crystalline solid with a nitrogen content of 21.21 percent and molecular weight of 264.20. The oxygen balance of the compound to CO2, H2O, and K2O is -42.4 percent. The anhydrous salt has a density of 2.21 grams per cubic centimeter and a melting point, with explosive decomposition, of 210°C. KDNBF is soluble to the extent of 0.245 grams per 100 grams of water at 30°C. Between the temperatures of 50C to 50°C the specific heat is 0.217 calories per gram per degree centigrade. KDNBF is used in primary compositions.

Lead Mononitroresorcinate (LMNR) has a nitrogen content of 3.89 percent, an NO2 content of 12.77 percent, a lead content of 57.51 percent, and a molecular weight of 360.30. The compound forms microscopic reddish brown crystals. LMNR has slow burning properties and a low combustion temperature. The compound is used in electric detonators with DLA as the spot charge to initiate a PETN base charge, as an upper charge, and as an ingredient in primary compositions.

Primary Compositions are mixtures of primary explosives, fuels, oxidizers, and other ingredients used to initiate detonation in high explosive charges or ignite propellants and pyrotechnics. The ingredients and the portions of the ingredients for individual priming compositions are determined empirically from the use the composition is intended for. Fuels commonly used in priming compositions are lead thiocyanate, antimony sulfide, and calcium silicide. The last two also serve to sensitize the composition to friction or percussion. Oxidizing agents include potassium chlorate and barium nitrate. Other ingredients include primary explosives and binders. The major determining factor in ingredient selection is the impetus which is to detonate the priming composition. The types of impetus commonly used are percussion and electrical.

Percussion Priming Compositions FA959, FA982, FA956, Compounds:

Normal lead styphnate
Tetracene
Barium nitrate
Antimony sulfide
Powdered zirconium
Lead dioxide
PETN
Aluminum
Gum Arabic

Stab Detonator Priming Compositions NOL130, PA101, NOL 60, Compounds:

Lead azide
Basic lead styphnate
Tetracene
Barium nitrate
Antimony sulfide
Powdered aluminum

Electric Priming Compositions I, II, III, IV, V, VI, Compounds:

Potassium chlorate
Lead mononitroresorcinate
Nitrocellulose
Lead thiocynate
DDNP
Charcoal
Nitrostarch
Titanium
Aluminum

Aliphatic Nitrate Esters compounds in this class are prepared by O-type nitration in which a nitro group is attached to an oxygen atom of the compound being nitrated.

1,2,4-Butanetriol Trinitrate (BTN) This explosive is also known as a, b, g-trihydroxybutane trinitrate and is sometimes referred to as BTTN. The compound is a light yellow liquid with a density of 1.520 at 20°C, a molecular weight of 241, a melting point of -27°C, an oxygen balance to CO2 of 17 percent, and a refractive index of 1.4738 at 20°C. The liquid has a viscosity of 62 centipoises at 20°C. 1,2,4- Butanetriol trinitrate is slightly soluble in water, miscible with alcohol, ether, acetone, and a solution of 2 parts ether and 1 part alcohol. BTN has a heat of formation of 368 calories per gram, a heat of combustion of 2,167 calories per gram, and a heat of detonation of 1,458 calories per gram. This compound is a good gelatinizer for nitrocellulose and can be used as a substitute for nitroglycerin in double-base propellants. Heat, vacuum stability, and volatility tests indicate more stability than nitroglycerin. Impact sensitivity is about the same as for nitroglycerin. Brisance, as measured by the sand test, is about the same: 49 grams crushed versus 51.5 grams for nitroglycerin or 47 grams for TNT. The five second explosion temperature is 230°C versus 220°C for nitroglycerin. BTN can be manufactured by the nitration of 1,2,4-butanetriol with a mixture of nitric and sulfuric acids.

Diethyleneglycol Dinitrate (DEGN) This explosive is also known as dinitrodiglycol or 2,2'-oxybisethanol dinitrate and is sometimes referred to as DEGDN. The compound is a clear, colorless, odorless liquid with a nitrogen content of 14.29 percent, a theoretical maximum density of 1.39 grams per cubic centimeter, an oxygen balance to C02 of-41 percent, and a molecular weight of 196. DEGN boils between 160° and 161°C and can, upon cooling, form a stable solid with a melting point of 2°C or remain liquid to a freezing point of -11.2° to 11.40°C. Other characteristics of the liquid are: refractive index at 20°C with sodium light, 1.450; viscosity at 20°C, 8.1 centipoises; vapor pressure at 20°C, 0.0036 torr; vapor pressure at 25°C, 0.00593 torr; vapor pressure at 600C, 0.130 torr; specific gravity, 1.385. At 60°C DEGN has a volatility of 0.19 milligrams per square centimeter per hour. At constant pressure, the heat of combustion is 2,792 calories per gram. The heat of formation is-99.4 kilogram calories per mole. The heat of detonation is 1,161 calories per gram. DEGN is readily soluble in ether, acetone, chloroform, benzene, nitrobenzene, toluene, nitroglycerin, and glacial acetic acid but is insoluble in ethanol, carbon tetrachloride, and carbon disulfide. Solubility in water at 25°C and 60°C is 0.40 and 0.46 gram per 100 grams, respectively. DEGN's chemical reactivity is similar to nitroglycerin's, but is less subject to hydrolysis and is not readily saponified by alcoholic sodium hydroxide. DEGN can be used as an explosive and can be used in propellants as a colloiding agent for nitrocellulose. Propellants based on DEGN and nitrocellulose develop relatively low temperatures and cause relatively little erosion of guns, but are unduly volatile.

Nitrocellulose (NC) or cellulose nitrate is a mixture of nitrates obtained by nitrating cellulose. Cellulose is a long chain polymer of anhydroglucose units (C5H10O5). The number of anhydroglucose units or degree of polymerization (DP) is variable. Cellulose used for preparation of military grades of nitrocellulose have a DP of approximately 1,000 to 1,500. Cellulose threads possess micellar structure and consist of numerous rod-like crystallites oriented with their long axis parallel to the thread axis, thus forming a fiber. Almost pure cellulose is found in the pith of certain plants, in absorbent cotton, and in some filter papers. Pure cellulose is most readily obtained from cotton by treating with a dilute acid or base solution then thoroughly washing with water. At the present time most of the cellulose for nitrocellulose preparation is obtained from coniferous wood, which is 50 to 60 percent cellulose. Another source is straw, which is 30 to 40 percent cellulose. The nitration of cellulose involves replacement of the hydrogen in the three hydroxyl (OH) groups in the anhydroglucose units with NO_2 groups. A representative formula for the nitrated cellulose may be written as $C_6H_7(OH)_x(ONO_2)_y$ where $x + y = 3$. The mononitrate, $x = 2$ and $y = 1$, has a nitrogen content of 6.76 percent; the dinitrate, $x = 1$ and $y = 2$, has a nitrogen content of 11.11 percent; the trinitrate, $x = 0$ and $y = 3$, has a nitrogen content of 14.14 percent. As a practical matter, however, any desired degree of nitration up to 14.14 percent may be obtained by adjusting the composition of the mixed acid used for nitration, the acid to cellulose ratio, the time of nitration, or the temperature of nitration. In nitrocellulose with less than 14.14 percent nitrogen, the NO_2 groups are distributed randomly along the entire length of the cellulose polymer, so x and y should be regarded as average values over the entire length of the chain. The nitrogen content determines the chemical and physical properties of any particular nitrocellulose. The five grades of nitrocellulose listed below are recognized and used.

Other Nitrocellulose Types:

- Pyroxylin or collodion,
- Pyrocellulose
- Guncotton
- High nitrogen nitrocellulose
- Blended nitrocellulose

Nitroglycerin (NG), glycerol trinitrate, or 1,2,3-propanetriol trinitrate, is a clear, colorless, odorless, oily liquid with a theoretical maximum density of 1.596 grams per cubic centimeter. Nitroglycerin has a sweet, burning taste and a molecular weight of 227.1. Nitroglycerin is soluble in one liter of water to the extent of only 0.173, 0.191, 0.228, and 0.246 gram at 20°, 30°, 50° and 60°C, respectively and is essentially nonhygroscopic when exposed to atmospheric humidity.

Nitrostarch (NS) is a mixture of nitrates obtained by nitrating starch. The general formula for starch is $C_6H_{10}O_5$. The structure of starch is the same as for nitrocellulose, with the exception that the polymer chains are spiral rather than straight. The starch molecule consists of approximately 1,000 anhydroglucose units. The nitration of starch involves replacement of the hydrogen in the three hydroxyl (OH) groups in the anhydroglucose units with NO_2 groups. A representative formula for the nitrated starch may be written as $C_6H_7(OH)_x(ONO_2)_y$ where $x + y = 3$. The NO_2 groups are distributed randomly along the entire length of the starch molecule, so x and y should be regarded as averages over the entire length of the chain. The following empirical formula can be employed to obtain y as a function of the nitrogen content N: $y = 162N/(1400 - 45N)$

Pentaerythritol Tetranitrate (PETN) is also known as 2,2-bis [(nitrooxy) methyl]-1,3-propanediol dinitrate; penthrite; or nitropenta and may be referred to as TEN. The compound is a white solid with a molecular weight of 316.2. PETN has two polymorphs: one with a tetragonal crystalline structure and the other with an orthorhombic crystalline structure. The phase change between the two polymorphs occurs at 130°C. The tetragonal crystals have a density of 1.778 grams per cubic centimeter and the orthorhombic crystals have a density of 1.716 grams per cubic centimeter. Normal manufacturing yields tetragonal crystals. The unit cell dimensions of the tetragonal crystals are a=9.38 Angstroms, b=9.38 Angstroms, and c =6.71 Angstroms. The dimensions for the orthorhombic crystals are a=13.29 Angstroms, b = 13.49 Angstroms, c = 6.83 Angstroms. There are two molecules per cell in the tetragonal form and four molecules per cell in the orthorhombic form. The interatomic distances have been determined as 1.50 Angstroms for the C-C bonds, 1.37 Angstroms for the C-O bonds, 1.36 Angstroms for O-N bonds, and 1.27 Angstroms for N-O bonds. PETN melts at 141.3°C. The boiling point is 160°C under a pressure of 2 torr; 180°C under a pressure of 50 torr. Under atmospheric pressure at temperatures above 21 0°C, PETN decomposes rapidly and in some cases detonates. The vapor pressure of solid PETN can be found by the empirical equation: $\log p = 16.73 - 7750/T$. PETN is more sensitive to initiation than nitrocellulose, RDX, or tetryl, as judged by the sand test. This is shown, also, by the fact that PETN with 35 percent of water present can be detonated by a No. 6 electric blasting cap, whereas RDX fails to explode if more than 14 percent of water is present. PETN is one of the most sensitive of the standardized military explosives.

Triethylene Glycoldinitrate (TEGN) This explosive is also referred to as TEGDN. The compound is a light yellow, oily liquid with a nitrogen content of 11.67 percent, a molecular weight of 240.20, and an oxygen balance to CO_2 of -66.6 percent. The melting point of the solid is - 19°C. Other characteristics of the liquid are: refractive index, 1.4540; viscosity at 20°C, 13.2 centipoises; vapor pressure at 25°C, less than 0.001 torr; volatility at 60°C, 40 milligrams per square centimeter per hour; and density, 1.335 grams per cubic centimeter. At constant pressure, TEGN's heat of combustion is 3428 calories per gram, heat of explosion is 725 kilocalories per kilogram, and heat of formation is -603.7 kilocalories per kilogram. TEGN is very soluble in acetone, ether, and a solution of 2 parts ether and 1 part ethanol. TEGN is soluble in carbon disulfide and slowly soluble in water. The primary use of TEGN is as a gelatinizing agent for nitrocellulose in propellants, but TEGN can also be used as a component in a liquid explosive, a plasticizer in the fabrication of flexible explosive sheets, and as a plasticizer in pytrotechnic flares.

1,1,1 Trimethylolethane Trinitrate (TMETN) This explosive is also known as metriol trinitrate and is sometimes referred to as MTN. The compound is a slightly turbid, viscous oil with a nitrogen content of 16.41 percent and a molecular weight of 255.15. TMETN has a melting point of -3°C and an apparent boiling point of 182°C, but this is merely the temperature at which decomposition becomes vigorous enough to resemble boiling. Other properties of the liquid are a density of 1.47 grams per cubic centimeter at 22°C and a refractive index of 1.4752 at 25°C. TMETN is practically insoluble in water. Less than 0.015 grams dissolved per 100 grams of water at up to 60°C. TMETN is soluble in alcohol and many other organic solvents. At 60°C TMETN's volatility is 24 milligrams per square centimeter. The heat of formation is 422 calories per gram at constant volume and 446 calories per gram at constant pressure. The heat of combustion is 2,642 calories per gram at constant volume with the water being liquid. In an acid bath, TMETN is hydrolyzed to the extent of 0.018 percent in 10 days at 220°C and 0.115 percent in 5 days at 60°C. TMETN can be used as a flash and erosion reducing additive in propellants and an ingredient of commercial explosives. TMETN alone does not gelatinize nitrocellulose unless the temperature is raised to 100°C, which would be dangerous. But if mixed with only 8 percent of metriol triacetate, gelatinization takes place at 80°C. When TMETN is mixed with nitroglycerin, the mechanical properties of double-base cast propellants are improved. Combinations with triethylene glycol dinitrate are used as plasticizers for nitrocellulose.

Cyclotetramethylenetetranitramine (HMX) is also known as: octahydro-1,3,5,7-tetranitro-1 ,3,5,7-tetrazocine; 1,3,5,7-tetranitro-1 ,3,5,7-tetrazacyclooctane; cyclotetramethylene tetranitramine; or octogen. HMX is a white, crystalline solid with a nitrogen content of 37.84 percent, a theoretical maximum density of 1.905 grams per cubic centimeter, a nominal density of 1.89 grams per cubic centimeter, a melting point of 285°C, and a molecular weight of 296.17. There are four polymorphs of HMX: an alpha, beta, gamma, and delta form. Each polymorph has a range of stability and there are differences among them in physical properties such as density, solubility, and refractive index. The most common polymorph is the beta form. The term HMX without an alpha, gamma or delta qualifier refers to the beta form throughout the rest of this text. The crystalline structure of beta HMX is monoclinic with a density of 1.903 grams per cubic centimeter. The unit cell dimensions are a=6.54 Angstroms, b=11.05 Angstroms, and c=8.70 Angstroms. Beta HMX is stable to about 102°C to 104.5°C, when the crystalline structure is converted to the alpha form. The crystals of the alpha form are orthorhombic with a density of 1.82 grams per cubic centimeter. The unit cell dimensions are a=15.14 Angstroms, b =23.89 Angstroms, c = 5.91 Angstroms. At approximately 160°C to 164°C the meta stable gamma form exists. The crystals of the gamma form are monoclinic with a density of 1.76 grams per cubic centimeter. The unit cell dimensions are a=10.95 Angstroms, b =7.93 Angstroms, and c = 14.61 Angstroms. Above the 160°C to 164°C range to the melting point, the delta form exists. The crystals of the delta form are hexagonal with a density of 1.80 grams per cubic centimeter. The unit cell dimensions are a=7.71 Angstroms and b=32.55 Angstroms. The polymorphs may also be prepared by precipitation from solution under various conditions. The beta form is precipitated from a solution of HMX in acetic acid, acetone, nitric acid, or nitrometrane with very slow cooling. The alpha form is precipitated from the same solution with more rapid cooling and the gamma form is precipitated with even more rapid cooling. The delta form is crystallized from solution such as acetic acid orbetachloroethyl phosphate, in which HMX is only slightly soluble. Very rapid chilling of the solution is required.

Cyclotrimethylenetrinitramine (RDX) This explosive is also known as: hexahydro-1,3,5-trinitro-1,3,5-triazine; 1,3,5-trinitro1,3,5-triazacyclohexane; cyclotrimethylene trinitramine; hexogen; cyclonite; or 1,3,5-trinitrotrimethylene-triamine.The compound is a white solid with a density of 1.806 grams per cubic centimeter, a nitrogen content of 37.84 percent, and a molecular weight of 222.13. RDX has orthorhombic crystals with a wide variety of habits; from needles when precipitated from HNO3, to plates when precipitated from acetic acid, to a massive form when precipitated from nitroethane or acetone. The unit cell dimensions are a=13.18 Angstroms, b = 1 1.57 Angstroms, and c = 10.71 Angstroms, and there are eight molecules per cell unit. On the Moh's scale RDX has a scratch hardness of 2.5. Other properties of pure RDX include a specific heat as shown in table 8-15 and a heat of combustion at constant pressure of 2,307.2 calories per gram. The heat of formation value is + 14.71 kilocalories per mole. RDX has an extremely low volatility. Pure RDX is used in press loaded projectiles but not in cast loaded projectiles because of extensive decomposition at the melting point. Cast loading is accomplished by blending RDX with a relatively low melting point substance. Compositions in which the RDX particles are coated with wax are called Composition A, in mixtures with TNT, Composition B, and blends with a nonexplosive plasticizer, Composition C. Straight RDX is used as a base charge in detonators and in some blasting caps, and as an oxidizer in specialized gun propellant.

Ethylenediamine Dinitrate (EDDN) This explosive is also designated EDD or EDAD. The compound is composed of white crystals with a specific gravity of 1.595 at 25/40, a nitrogen content of 30.10 percent, an oxygen balance to C02 of-25.8 percent, a melting point of 185° to 187°C, and a molecular weight of 186.13. The compound is soluble in water, but insoluble in alcohol or ether. EDDN has a heat of combustion of 374.7 kilocalories per mole at constant pressure, a heat of formation of 156.1 kilocalories per mole, and a heat of explosion of 127.9 to 159.3 kilocalories per mole. Eutectics are formed with ammonium nitrate, but EDDN is immiscible with molten TNT. An aqueous solution of EDDN is distinctly acidic. EDDN has been used to a limited extent as a bursting charge pressed in shells and as a cast charge in eutectic mixtures with ammonium nitrate. Mixtures with wax were used in boosters during World War II by the Germans.

Ethylenedinitramine (Haleite) This compound is also known as N’ N'-dinitroethylene diamine; ethylene dinitramine; or 1,2-dinitrodiaminoethane, and is sometimes designated EDNA. The name Haleite is in recognition of the development of this compound as a military explosive by the late Dr. G. C. Hale of Picatinny Arsenal. The compound is white with an orthorhombic crystal structure, a nitrogen content of 37.33 percent, anoxygen balance to CO2 of-32 percent, an oxygen balance to CO of-10.5 percent, and a molecular weight of 150.10. The density of the crystals vary from 1.66 to 1.77 depending on the solvent from which the crystallization took place.

Nitroguanidine (NQ) This explosive is also known as picrite or guanylnitramine. The compound has a nitrogen content of 53.84 percent, an oxygen balance to CO2 of -30.8 percent, a theoretical maximum density of 1.81 grams per cubic centimeter, a nominal density of 1.55 to 1.75 grams per cubic centimeter, and a molecular weight of 104.1. The melting point of nitroguanidine varies somewhat with the rate of heating. The pure material melts with decomposition at 232°C, but values from 220°C to 250°C are obtainable with various heating rates. At least two crystalline forms exist for nitroguanidine; alpha and beta.

2, 4,6Trinitrophenylmethylnitramine (Tetryl) This explosive is also known as: 2,4,6tetranitro-N-methyl aniline; N-methyl-N,2,4,6tetranitro-benzenamine; 2,4,6-trinitrophenylmethylnitramine; tetranitromethylamulene; or picrylmethylnitramine and is sometimes referred to as pyronite, tetrylit, tetralite, tetralita, or CE. The compound is colorless when freshly prepared and highly purified, but rapidly acquires a yellow color when exposed to light. Tetryl has a nitrogen content of 24.4 percent, an oxygen balance to CO2 of-47 percent, a nominal density of 1.71 grams per cubic centimeter with a theoretical maximum density of 1.73 grams per cubic centimeter, and a molecular weight of 287.15. The melting point of the pure substance is 129.45°C and of the technical grade, 129°C.

Nitroaromatics. Compounds in this class are prepared by C-type nitration in which a nitrogroup is attached to a carbon atom of the compound being nitrated.

Ammonium Picrate This explosive is also known as ammonium 2,4,6-trinitrophenolate, explosive D, and Dunnite. The compound has a nitrogen content of 22.77 percent, an oxygen balance to C02 of- 52 percent, a maximum crystal density of 1.717 grams per cubic centimeter, a nominal density of 1.63 grams per cubic centimeter, a melting point with decomposition of about 280°C and a molecular weight of 246. Ammonium picrate exists in a stable form as yellow, monoclinic crystals and a meta stable form as red, orthorhombic crystals. The unit cell dimensions are a =13.45 Angstroms, b

1,3-Diamino-2,4,6-Trinitrobenzene (DA TB) This explosive is also known as 2,4,6trinitro-1,3-diaminobenzene; 2,4,6-trinitro-7,3benzenediamine trinitro-m-phenylenediamine; or 2,4,6-trinitro-1 ,3-diaminobenzol and may be referred to as DATNB. The compound is a yellow, crystalline solid with a nitrogen content of 28.81 percent, a melting point of 2860C to 301°C with decomposition, and a molecular weight of 243.14.

1,3,5Triamino-2, 4,6Trinitrobenzene (TA TB) This explosive is also known as 2,4,6trinitro-1,3,5-benzenetriamine and may be referred to as TATNB. TATB has a nitrogen content of 32.56 percent, an oxygen balance to C02 of -55.78 percent, and a molecular weight of 258.18. TATB is yellow but exposure to sunlight or ultraviolet light causes a green coloration which, with prolonged exposure, turns brown. The compound has a theoretical maximum density of 1.937 grams per cubic centimeter and a nominal density of 1.88 grams per cubic centimeter. An instantaneous hot bar decomposition temperature of 450°C to 451 °C was reported with rapid thermal decomposition above 320°C. The structure of the crystalline lattice of TATB contains many unusual features. Some of these are the extremely long C-C bonds in the benzene ring, the very short C-N bonds, amino bonds, and the six furcated hydrogen bonds. Evidence of a strong intermolecular interaction, hydrogen bonds, in TATB is indicated by the lack of an observable melting point and very low solubility. The intermolecular network results in a graphite-like lattice structure with the resulting properties of lubricity and intercalaction.

2,4,6-Trinitrotoluene (TNT) This explosive is also known as trotyl, tolit, triton, tritol, trilite, and 1-methyl-2,4,6-trinitrobenzene. TNT has been the most widely used military explosive from World War I to the present time. The advantages of TNT include low cost, safety in handling, fairly high explosive power, good chemical and thermal stability, favorable physical properties, compatibility with other explosives, a low melting point favorable for melt casting operations, and moderate toxicity. There are six possible ring nitrated TNT isomers. The alpha isomer, which is the one of military interest is symmetrical and will be referred to as TNT. The other five meta isomers will be identified by the Greek letters beta through eta excluding zeta. TNT is a yellow, crystalline compound with a nitrogen content of 18.5 percent, an oxygen balance to CO2 of-73.9 percent, a molecular weight of 227.13, and a melting point of 80°C to 81°C. TNT shows no deterioration after 20 years storage in a magazine.

Impurities Present in TNT

2,4,5-Trinitrotoluene
2,3,4-Trinitrotoluene
2,3,6-Trinitrotoluene
2,3,5-Trinitrotoluene
3,4,5-Trinitrotoluene
2,6-Dinitrotoluene
2,4-Dinitrotoluene
2,3-Dinitrotoluene
2,5-Dinitrotoluene
3,4-Dinitrotoluene
3,5-Dinitrotoluene
1,3-Dinitrobenzene
1,3,5-Trinitrobenzene
2,4,6-Trinitrobenzyl alcohol
2,4,6-Trinitrobenzaldehyde
2,4,6-Trinitrobenzoic acid
Alpha-nitrato-2,4,6-trinitrotoluene
Tetranitromethane
2,2'-Dicarboxy-3,3',5,5'-tetranitroazoxybenzene (white compound)
2,2',4,4',6,6'-Hexanitrobibenzyl (HNBB)
3-Methyl-2',4,4',6,6'-pentanitrodiphenylmethane(MPDM)
3,3',5,5'-Tetranitroazoxybenzene

Compositions are explosives in which two or more explosive compounds are mixed to produce an explosive with more suitable characteristics for a particular application. Generally, the characteristics of the composition are intermediate between the characteristics of the individual explosive ingredients. For example, the addition of TNT to RDX reduces brisance somewhat but considerably improves sensitivity. The composition explosives are categorized by the number of ingredients contained in the mixture.

Binary Mixtures

Amatols are binary mixtures of ammonium nitrate and TNT. The percentages of ammonium nitrate and TNT are reflected in the nomenclature for each mixture, for example, 80/20 amatol consists of 80 percent ammonium nitrate and 20 percent TNT. Ammonium nitrate is insoluble in TNT. The chemical and physical properties of the constituents determine the properties of the amatol. The mixture begins to melt at TNT's melting point but the ammonium nitrate, which has a higher melting point, remains solid.

Composition A explosives consist of a series of formulations of RDX and a desensitizer. Compositions A and A2 contain the same percentages of materials as composition A3 but the type of wax used and the granulation requirements for the RDX are different. Composition A contains beeswax, while composition A2 contains a synthetic wax. Compositions A and A2 are no longer used. All of the composition A explosives are press loaded. The density of composition A3 is 1.47 and 1.65 grams per cubic centimeter when pressed to 20,685 kilopascals (3,000 pounds per square inch) and 82,740 kilopascals (12,000pounds per square inch), respectively.

Composition B type explosives are mixtures of RDX and TNT. Composition B refers to mixtures of approximately 60 percent RDX and 40 percent TNT. Other portions of RDX and TNT are called cyclotols.

Composition C During World War II, the British used a plastic demolition explosive that could be shaped by hand and had great shattering power. As standardized by the United States, this explosive was designated as composition C and contained 88.3 percent RDX and 11.7 percent of a nonexplosive oily plasticizer. Included in the plasticizer was 0.6 percent lecithin, which helped to prevent the formation of large crystals of RDX which would increase the sensitivity of the composition.

Ednatols are mixtures of halite (ethylene dinitramine) and TNT. The most used haleite/TNT portions are 60/40, 55/45, and 50/50. Ednatols are yellowish, uniform blends with a melting point of 80°C. The eutectic temperature is about 80°C. In an extrudation test at 65°C there was no extrudate. Ednatols are considered satisfactory for bursting charges in ammunition. All of the following data in the discussion of the properties of ednatol refer to the 55/45 mixture. 55/45 Ednatol has an oxygen balance to carbon dioxide of -51 percent and to carbon monoxide of - 17 percent. The density of the cast explosive is 1.62 grams per cubic centimeter, which is four percent greater than that of cast TNT or haleite pressed under 206,850 kilopascals (30,000 pounds per square inch).

LX-14 is an explosive which consists of 95.5 percent HMX and 4.5 percent estane 5702-F1. The mixture is a white solid with violet spots. LX-14 has a theoretical maximum density of 1.849 grams per cubic centimeter, a nominal density of 1.83 grams per cubic centimeter, and a melting point of greater than 270°C, with decomposition. The heat of formation is 1.50 kilocalories per mole. The calculated heats of detonation are 1.58 kilocalories per gram with liquid water and 1.43 kilocalories per gram with gaseous water. At a density of 1.835 grams per cubic centimeter the detonation velocity is 8,830 meters per second.

Octols are mixtures of HMX and TNT. Octol is used as an oil well formation agent and in fragmentation and shaped charges. In fragmentation tests using a 105 millimeter M1 shell, 15 percent more fragments are produced and the average velocity of the fragments is 100 meters per second faster than with a similar shell loaded with composition B. This improvement is attributed to both the higher rate of detonation of octol and the greater density of octol which permits a greater weight of explosive in the same volume.

Pentolite are castable explosive mixtures containing PETN and TNT. The most commonly used blend consists of 50/50 PETN/TNT. Other blends such as 75/25, 40/60, 30/70, and 10/90 have been occasionally employed but the 50/50 blend is superior in the characteristics of sensitivity to initiation, brisance, and suitability for melt loading. 87 percent TNT and 13 percent PETN form a eutectic with a freezing point of 76.7°C. Cast 50/50 pentolite, therefore, consists of 42.2 percent PETN, and 57.8 percent of the eutectic mixture.

Picratol is a mixture of 52 percent ammonium picrate and 48 percent TNT. Molten TNT has little or no solvent action on ammonium picrate, and consequently, cast picratol consists essentially of a physical mixture of crystals of the two explosives. The density of cast picratol is 1.61 to 1.63. This permit's a weight of charge almost equal to that

Tetrytols are light yellow to buff mixtures of TNT and tetryl. As is the case for tetryl, tetrytols are no longer used by the United States but are still being used by other nations including various NATO allies. Tetrytols resemble tetryl more closely than they resemble TNT. They are more powerful but less sensitive than TNT. Tetrytols can be cast into munitions, which is an advantage over press loading. Table 8-73 compares the physical characteristics of various detritus compositions.

Ternary Mixtures

Amatex 20 The mixture has a nominal density of 1.61 grams per cubic centimeter and is used as a filler in ammunition items.

Amatex 20 consists of:

RDX	40 percent
TNT	40 percent
Ammonium nitrate	20 percent

Ammonal

Ammonals are mixtures containing, as principle ingredients, ammonium nitrate and powdered aluminum incorporated with high explosives such as TNT, DNT, and RDX. Powdered carbon was also used in earlier ammonals. In the ammonals that do not contain carbon, the mixture of ammonium nitrate and high explosive detonates developing a very high temperature which causes volatilization of the aluminum powder. In general, ammonals are fairly insensitive and stable mixtures but are hygroscopic due to the presence of ammonium nitrate. In the presence of moisture, ammonals react with the same metals as amatols: copper, bronze, lead, and copper plated steel.

(HTA-3) are mixtures of HMX, TNT, and aluminum

Minol-2 are mixtures of TNT, ammonium nitrate, and aluminum.

Torpex is a silvery white solid when cast. The composition of torpex is 41.6 percent RDX, 39.7 percent TNT, 18.0 percent aluminum powder, and 0.7 percent wax.

Quanternary Mixtures

Depth bomb explosive (DBX) is the only explosive covered under quanternary mixtures. DBX consists of:

TNT	40 percent
RDX	21 percent
Ammonium nitrate	21 percent
Aluminum	18 percent

Industrial Explosives

Dynamites Military operations frequently necessitate excavation, demolition, and cratering operations for which the standard high explosives are unsuited. Recourse is made to commercial and special compositions. Commercial blasting explosives, with the exception of black powder, are referred to as dynamites although in some cases they contain no nitroglycerin.

Ammonium nitrate fuel oil explosives (ANFO) When ammonium nitrate is mixed with approximately 5.6 percent of a combustible material such as fuel oil, the heat liberated on detonation is increased by almost three-fold.

CHAPTER 9
UNITED STATES PROPELLANTS

Introduction Selection of a propellant for an application is made on the basis of the requirements of that specific application. In general, guns are designed to meet specified performance standards and withstand a specific pressure in the barrel. With a knowledge of the properties of the constituents normally used for propellants, the propellant designer creates a formulation to satisfy the performance standards and limitations of the gun. When ignited, the propellant produces large quantities of hot, gaseous products. Complete combustion or deflagration of the propellant occurs in milliseconds in guns and the pressure produced accelerates the projectile down the barrel.

Single-base propellants M1, M6, M10, and IMR.

Double-base gun propellants M2, M5, M8 and M18.

Triple-base gun propellants contain nitroguanidine as additional energizer which increases the energy content of the formulation without raising the flame temperature.

Composite propellants, used in solid fuel rockets, contain a polymer binder, a fuel, and an oxidizer.

Ball Propellants

Propellants Compounds: M1, M2, M5, M6, M8, M10, M31, M30, IMR, M18
Nitrocellulose (NC)
Nitrogen
Nitroglycerin
Barium nitrate
Potassium nitrate
Potassium sulfate
Lead carbonate
Nitroguanidine
Dinitrotoluene
Dibutylphthalate
Diethylphthalate
Diphenylamine
Ethyl centralite
Graphite
Cryolite
Ethyl alcohol (residual)

Diphenylamine, (C6H5)2NH, is an ammonia derivative in which two of the hydrogens have been replaced by phenyl groups. Each phenyl ring has three hydrogens which can be replaced with nitro groups. Therefore, DPA can be nitrated to the hexanitrate by absorbing the nitrogen oxides produced during the decomposition of nitrocellulose. DPA is nitrated relatively easily and the reaction is not exothermic. During the decomposition of nitrocellulose, DPA nitrates to the following compounds in succession.

N-nitrosodiphenylamine
2-nitrodiphenylamine
4-nitrodiphenylamine
N-nitroso-2-nitrodiphenylamine
N-nitroso-4-nitrodiphenylamine
4,4', 2,4', 2,2', and 2,4-dinitrodiphenylamines
N-nitroso-4, 4'-dinitrodiphenylamine
N-nitroso-2, 4'-dinitrodiphenylamine
2, 4, 4' and 2, 2', 4-trinitrodiphenylamines
2,2', 4,4'-tetranitrodiphenylamine
2,2', 4,4', 6-pentanitrodiphenylamine
Hexanitrodiphenylamine

The propellant does not start to become unstable until most of the diphenylamine has been converted to hexanitrodiphenylamines. A very accurate test to measure the remaining safe storage life in a propellant lot is to analyze the distribution profile of the nitro DPAs. Only about one percent DPA can be added to a propellant because its nitrated products change the ballistic properties.

Centralite I (which is also called ethyl centralite or symmetrical diethyldiphenylurea), OC [N-(C2H5) (C6H5)]2, was developed in Germany for use in double base propellants. The compound acts as a stabilizer, gelatinizer, and waterproofing agent. Unlike diphenylamine, centralite can be used in relatively large proportions and some propellant compositions contain as much as eight percent of this material. Like diphenylamine, centralite is nitrated by the products of nitrocellulose decomposition. The following compounds are formed successively, as many as four being present simultaneously, as deterioration of the powder proceeds.

4-nitrocentralite
4,4' dinitrocentralite
N-nitroso-N-ethylaniline
N-nitroso-N-ethyl-4-nitraniline
2,4, dinitro-N-ethyl-aniline

Centralite II (which is also called methyl centralite or symmetrical dimethyl diphenylurea), OC[N(CH3) (C6H5)]2, also has been used as a stabilizer but is not considered to be as effective as the ethyl analogue

Three akardites, or acardites, are used to stabilize propellants. Akardite II is often used in DEGN containing propellants.

Pyrotechnic Devices

Military Explosives (Chemistry) 30 September 1984

CHAPTER 10
UNITED STATES PYROTECHNICS

Pyrotechnics are used to send signals, to illuminate areas of interest, to simulate other weapons during training, and as ignition elements for certain weapons.(1)

All pyrotechnic compositions contain oxidizers and fuels. Additional ingredients present in most compositions include binding agents, retardants, and waterproofing agents. Ingredients such as smoke dyes and color intensifiers are present in the appropriate types of compositions.

Oxidizers: are substances in which anoxidizing agent is liberated at the high temperatures of the chemical reaction involved.

Fuels: include finely powdered aluminum, magnesium, metal hydrides, red phosphorus, sulfur, charcoal, boron, silicon, and suicides. The most frequently used are powdered aluminum and magnesium.

Binding agents: include resins, waxes, plastics, and oils. These materials make the finely divided particles adhere to each other when compressed into pyrotechnic items.

Retardants are materials that are used to reduce the burning rate of the fuel-oxidizing agent mixture, with a minimum effect on the color intensity of the composition.

Waterproofing agents are necessary in many pyrotechnic compositions because of the susceptibility of metallic magnesium to reaction with moisture, the reactivity of metallic aluminum with certain compounds in the presence of moisture, and the hygroscopicity of nitrates and peroxides.

Color intensifiers:
hexachloroethane (C2CI6)
hexachlorobenzene (C6CI6)
polyvinyl chloride
dechlorane (C1oCI12).

Smoke dyes are azo and anthraquinone dyes. These dyes provide the color in smokes used for signaling, marking, and spotting.

Flares and Signals The illumination provided by a flare is produced by both the thermal radiation from the product oxide particles and the spectral emission from excited metals.

Infrared Flare Formulas:

Silicon
KNO3
CsNO3
RbNO3
Hexamethylene
tetramine
Epoxy resin

Red-Green Flare System:

Barium nitrate
Strontium nitrate 13
Potassium perchlorate
Magnesium
Dechlorane
Polyvinyl acetate resin

Signal flares are smaller and faster burning than illuminating flares. Various metals are added these compositions to control the color of the flame.

Colored and White Smoke The pyrotechnic generation of smoke is almost exclusively a military device for screening and signaling. Screening smokes are generally white because black smokes are rarely sufficiently dense. Signal smokes, on the other hand, are colored so as to assure contrast and be distinct in the presence of clouds and ordinary smoke.

Venturi thermal generator type. The smoke producing material and the pyrotechnic fuel block required to volatilize the smoke material are in separate compartments. The smoke producing material is atomized and vaporized in the venturi nozzle by the hot gases formed by the burning of the fuel block.

Burning type. Burning type smoke compositions are intimate mixtures of chemicals. Smoke is produced from these mixtures by either of two methods. In the first method, a product of combustion forms the smoke or the product reacts with constituents of the atmosphere to form a smoke. In the second method, the heat of combustion of the pyrotechnic serves to volatilize a component of the mixture which then condenses to form the smoke. White phosphorus, either in bulk or in solution, is one example of the burning type of smoke generator.

Explosive dissemination type. The smoke producing material is pulverized or atomized and then vaporized, or a preground solid is dispersed by the explosion of a bursting charge. The explosive dissemination smoke generator may contain metallic chlorides which upon dispersal, hydrolyze in air. Examples are titanium, silicon, and stannic tetrachloride.

Smoke Agent Mixtures:

White phosphorus
Sulfur trioxide

FS agent
HC mixture
FM agent
Crude oil

The preferred method of dispersing colored smokes involves the vaporization and condensation of a colored organic volatile dye. These dyes are mixed to the extent of about 50 percent with a fuel such as lactose (20 percent) and an oxidizer (30 percent) for which potassium chlorate is preferred.

Tracers and Fumers The principal small arms application of military pyrotechnics is in tracer munitions where they serve as incendiaries, spotters, and as fire control. Two types of tracers are used. The difference between the two types is the method of tracking. The more frequently used tracer uses the light produced by the burning tracer composition for tracking. Smoke tracers leave a trail of colored smoke for tracking. Red is the flame color most often employed in tracers.

Igniter and Tracer Compositions

Strontium peroxide
Magnesium
1-136 Igniter
Calcium resinate
Barium peroxide
Zinc stearate
Toluidine red (identifier)
Strontium nitrate
Strontium oxalate
Potassium perchlorate
Polyvinyl chloride

Incendiaries Two types of incendiaries are commonly used. The traditional type is a bomb containing a flammable material. These materials include thermite (a mixture of aluminum and rust), phosphorus, and napalm. In addition, the case of the bomb may be constructed of a material such as magnesium that will burn at a high temperature once ignited.Depleted uranium is used extensively in pyrotechnics which have armor piercing capabilities.

Depleted uranium deficient in the more radioactive isotope U235, is the waste product of the uranium enrichment process. The depleted uranium is formed into projectiles that can penetrate armor because of their high density and mechanical properties. The impact of the projectile causes the uranium to form many pyrophoric fragments which can ignite fuel and munition items.

Pyrophoric Metals

U	Uranium
Th	Thorium
Zr	Zirconium
Hf	Hafnium

Ce	Cerium
La	Lanthanum
Pr	Praseodymium
Nd	Neodymium
Sm	Samarium
Y	Yttrium
Ti	Titanium

Delays and Fuses Delay compositions are mixtures of oxidants and powdered metals which produce very little gas during combustion.

Photoflash Compositions Photoflash compositions are the single most hazardous class of pyrotechnic mixtures. The particle size of the ingredients is so small that burning resembles an explosion. The various photoflash devices are similar, differing principally in size and the amount of delay.

Colored smokes:

Yellow: Auramine hydrochloride
Green: 1,4-Di-p-toluidinoanthraquinone with auramine hydrochloride
Red: 1-Methylanthraquinone
Blue: Not suitable for signaling because of excessive light scatter.

Currently used dyes:

Orange: 1-(4-Phenylazo)-2-naphthol
Yellow: N, N-Dimethyl-p-phenylazoaniline
Blue: 1,4-Diamylaminoanthraqdinone

Black Powders Used in Pyrotechnics

- Potassium nitrate
- Sodium nitrate
- Charcoal
- Coal (semibituminous)
- Sulfur

Ignition Mixtures Components

- Aluminum (powdered)
- Ammonium dichromate
- Asphaltum
- Barium chromate
- Barium peroxide
- Boron (amorphous)
- Calcium resinate
- Charcoal
- Diatomaceous earth (See also superfloss)
- Fe203 (Red)
- Fe304 (Black)
- Potassium nitrate
- Potassium perchlorate

Laminac
Magnesium (powdered)
Sodium nitrate
Nitrocellulose
Parlon (chlorinated rubber)
Pb02 -
Pb304
Sr peroxide
Sugar
Superfloss
Titanium
Toluidine red toner
Vegetable oil
Vistanex (polyisobutylene)
Zinc Stearate
Zirconium

Table 4. Pyrotechnic Munitions Chemicals

Chemicals found in practice and pyrotechnic munitions [1] [2]

- Aluminum
- Ammonium chloride
- Ammonium perchlorate
- Amorphous boron
- Antimony sulfide
- Antimony metal powder
- Anthracene
- Asphaltum
- Barium nitrate
- Barium chromate
- Barium chlorate
- Barium peroxide
- Barium sulfate
- Bismuth tetroxide
- Butyl rubber
- Calcium resinate
- Calcium fluoride
- Carbon tetrachloride
- Calcium metal
- Cobalt naphthenate
- Copper carbonate
- Zirconium hydride
- Polychlorotrifluoroethylene
- Lead monoxide
- Saltpeter
- Calcium Resinate
- Red Gum
- Dextrin
- Auramine Hydrochloride
- Copper powder
- Chlorinated rubber (Parlon)
- Cupric oxide
- Cuprous chloride
- Calcium silicide
- Cellulose-nitrate-plastic
- Dichloromethane
- Gilsonite
- Graphite
- Hexachlorobenzene
- Hexachloroethane (HC)
- Iron oxide
- Infusorial earth
- Lead dioxide
- Lithium peroxide
- Lithium perchlorate
- Magnesium
- Magnese dioxide
- Mercurous chloride
- Polyisobutylene (vistanex)
- Potassium iodate
- Zinc stearate
- Manganese
- Lead chromate
- Cupric Oxide
- Sulphur
- Barium Oxalate
- Ammonium Nitrate
- Stearin
- Potassium chromate
- Potassium chlorate
- Polyvinyl acetate
- Polyvinylchloride (PVC)
- Perchlorate
- Potassium dichromate
- Potassium perchlorate
- Resin (laminac)
- Red phosphorous
- Selenium
- Sodium oxalate
- Sodium bicarbonate
- Stearic acid
- Strontium nitrate
- Strontium carbonate
- Strontium nitrate
- Strontium peroxide
- Shellac
- Tellurium
- Titanium
- Tungsten
- White phosphorous
- Magnesium aluminum
- Diatomaceous Earth
- Charcoal
- Calcium Phosphide
- Adhesive, Dextrin
- Orange Shellac
- Arsenic Disulphide

Dyes

- 1-(2-Methoxyphenylazo)-2-Napthol Sudan Red G
- 1, 4 Dimethylamino Anthraquinone Fast Blue B
- 2-(4-Dimethylamino Phenylazo) Napthalene
- Indanthrene Dye Golden Yellow GKAC
- 4-Dimethylamino Azobenzene
- 1, 4 Diphenyl Toluidino Anthraquinone
- 1-Amino Anthraquinone Fast Red A1
- 4-Methylamino Anthraquinone

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[1] Book: Military Pyrotechnics, 1919; Henry B. Faber; Dean of Pyrotechnic Schools Ordnance Department U.S. Army

[2] Book: Military and Civilian Pyrotechnics, 1968; Dr. Herbert Ellern

Table 5. 23 Pyrotechnic munitions chemicals also used as Pesticides

Chemical	CAS	Pesticide/Biocide/Repellant
Arsenic sulfide	12344-68-2 12612-21-4	Herbicide, Insecticide, Rodenticide
Ammonium Nitrate	6484-52-2	Microbiocide, Rodenticide
Ammonium Chloride	12125-02-9	Algaecide, Microbiocide
Anthracene	120-12-7	Herbicide, Insecticide, Rodenticide
Barium nitrate	10022-31-8	Repellant
Calcium phosphide	1305-99-3	Rodenticide
Carbon tetrachloride	56-23-5	Fumigant,
Cobalt naphthenate	61789-51-3	Fungicide, Insecticide
Copper powder	7440-50-8	Fungicide,
Copper carbonate	12069-69-1	Algaecide, Fungicide, Insecticide
Cupric oxide	1317-38-0	Fungicide, Insecticide
Cuprous chloride	7758-89-6	Fungicide
Dichloromethane	75-09-2	Dog and Cat Repellant
Diatomaceous Earth	61790-53-2	Insecticide, Molluscicide
Iron oxide	1309-37-1	Herbicide
Potassium chlorate	3811-04-9	Defoliant, Herbicide, Microbiocide
Saltpeter	7757-79-1	Microbiocide, Rodenticide
Sodium bicarbonate	144-55-8	Fungicide
Sodium oxalate	62-76-0	Microbiocide
Sulphur	7704-34-9	Fungicide, Insecticide
Stearic acid	57-11-4	Adjuvant
Naphthalene (smoke dye)	91-20-3	Insecticide, insect repellant
Anthraquinone (smoke dye) (found in 4 smoke dye formulas)	84-65-1	Bird Repellant

Note: May explain why training areas are devoid of a robust insect and bird population.

Pesticide Use Information Source:
Pesticide Action Network North America: www.pesticideinfo.org/Search_Chemicals.jsp

Table 6. Pesticides known to have been used at Fort Ord

(potentially used in all training areas)

48 Pesticides known as used at Fort Ord

Calcium Cyanide Gas
DDD
Malathion
Warfarin
Altosid SR-10
Sevin (Carbyrl Dust)
Chlorophacinone
Heptachlor Epoxide
Derzvan
Pyrethrum
Gophercide
Monuron
Aertex
Trexsan
Diquat
Enide
Banvel
Mercury
DDE
Chlordane
Diazinon
Tordon 101
1080
Zinc Phosphide
Gamma-BHC
Methyl Bromide
Permaguard
Diphacin
Ded-Weed Silvex LV
Paraquat CL
Amino Triazole
Tok-E-25
Metalde HTDE
DDT
2,4-D
Dieldrin
Baygon
Hyvar X
Diphacinone
Endrin
Derzan-T
Cyntroid 3-EC
Ficam W
Weed-Rhap LY-4P
Simazine
Betasan
Amitrol-T
Surflan
Arochlor 1254

Note: Pesticides where applied to training areas for decades. Pesticides were applied by air and ground to manage pests (rodents, insects, fungi, and vegetation) the extent of which is unknown.

Former Fort Ord Pesticide Use; Research Documents:

Available at Fort Ord Administrative Record ; http://fortordcleanup.com/adminrec/arsearch.asp
enter record number, example: BW-0013

1) Fort Ord Installation Assessment 1983; BW-0013, pesticide types and uses
2) Fort Ord Base Closure Preliminary Assessment1990; BW-2427, pesticide types and uses
3) Fort Ord Literature review and Base Inventory Report Vol I, 1991; RI/FS BW-0136
4) Fort Ord Basewide Background Soil Investigation draft 1992; BW-0289
5) Fort Ord Basewide Background Soil Investigation draft final 1993; BW-0352
6) Fort Ord Basewide Background Soil Investigation final 1995; BW-1283E Basewide RI/FS
7) Fort Ord 2003 Burn ATSDR Health Consultation; OE-0522

Table 7. Munitions Chemicals looked for in training areas transferred to the Fort Ord Reuse Authority (FORA) for development

All these development parcels are known training areas

Historical Area (HA) Training Areas and total chemicals looked for:

HA-161,CSUMB Booby Traps, Mines, Projectiles, Pyrotechnics - Development

TPH-Diesel	TPH-Motor Oil	Bis(2-ethylhexyl)phthalate
TPH-Gasoline	Di-n-butyl phthalate	Di-n-octylphthalate
Antimony	Copper	Lead
Cadmium		

HA-175, OE-45 Tactical Training Area - Development

No Sampling Required

HA-103, OE-13B Mortar Range / Parker Flats portion - MST/Horse Park Development

No Sampling Required: based on off-site sampling results

HA-110, DRO.1 Site 39 Multi-use Training/Impact Area - Del Rey Oaks Development

No Sampling Required: based on off-site sampling results

HA-111, DRO.2 Site 39 Multi-use Training/Impact Area - Del Rey Oaks Development

No Sampling Required: based on off-site sampling results

HA-112, SEA.1 Site 39 Multi-use Training/Impact Area - Seaside Development

No Sampling Required: based on “no stressed vegetation or impacts to soil”

HA-112, SEA.2 Site 39 Multi-use Training/Impact Area - Seaside Development

No Sampling Required: based on “no stressed vegetation or impacts to soil”

HA-112, SEA.3 Site 39 Multi-use Training/Impact Area - Seaside Development

No Sampling Required: based on “no stressed vegetation or impacts to soil”

HA-112, SEA.4 Site 39 Multi-use Training/Impact Area - Seaside Development

No Sampling Required: based on “no stressed vegetation or impacts to soil”

HA-116, MOCO1 Site 39 Multi-use Training/Impact Area - Monterey Co Development

No Sampling Required: based on “no MEC was identified during sampling”

HA-117, MOCO2 Site 39 Multi-use Training/Impact Area - Monterey Co Development

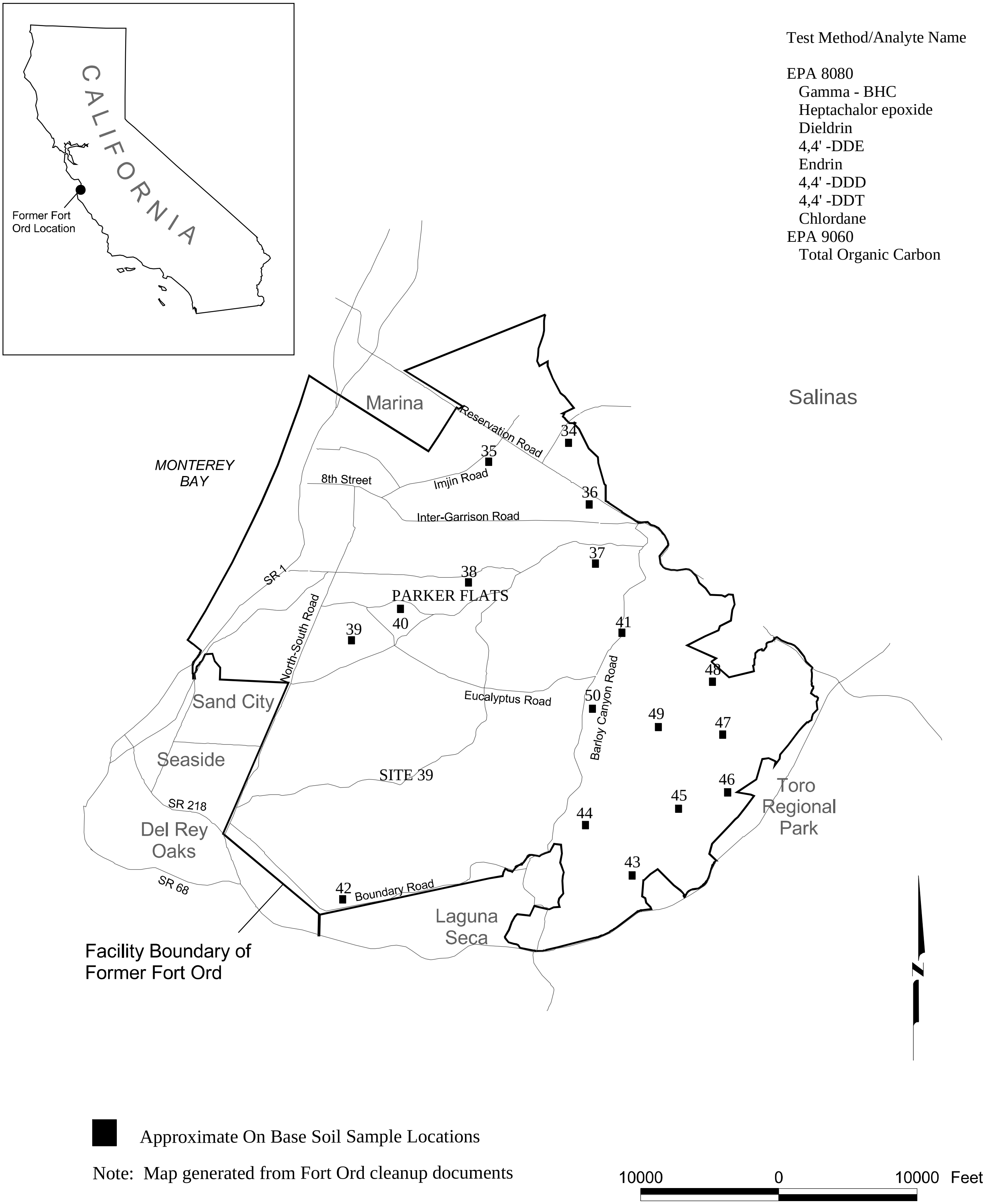
Antimony	Copper	Lead

HA-118, Site 39 Site 39 Impact Area - Habitat Management Area

2,4,6-Trinitrotoluene	2-Amino-trinitrotoluene	4-Amino-dinitrotoluene
HMX	RDX	1,3,5-Trinitrobenzene
Tetryl		

Note: Pyrotechnics were used day and night, over a 77 year period. Pyrotechnics were used for all types of troops training including non-live fire, live-fire, bivouac, and maneuvers activities.

Compiled from Fort Ord documents AR BW-2300J, Basewide Range Assessment Reports Final 2009



Test Method/Analyte Name

EPA 8080
- Gamma - BHC
- Heptachalor epoxide
- Dieldrin
- 4,4' -DDE
- Endrin
- 4,4' -DDD
- 4,4' -DDT
- Chlordane

EPA 9060
- Total Organic Carbon

■ Approximate On Base Soil Sample Locations

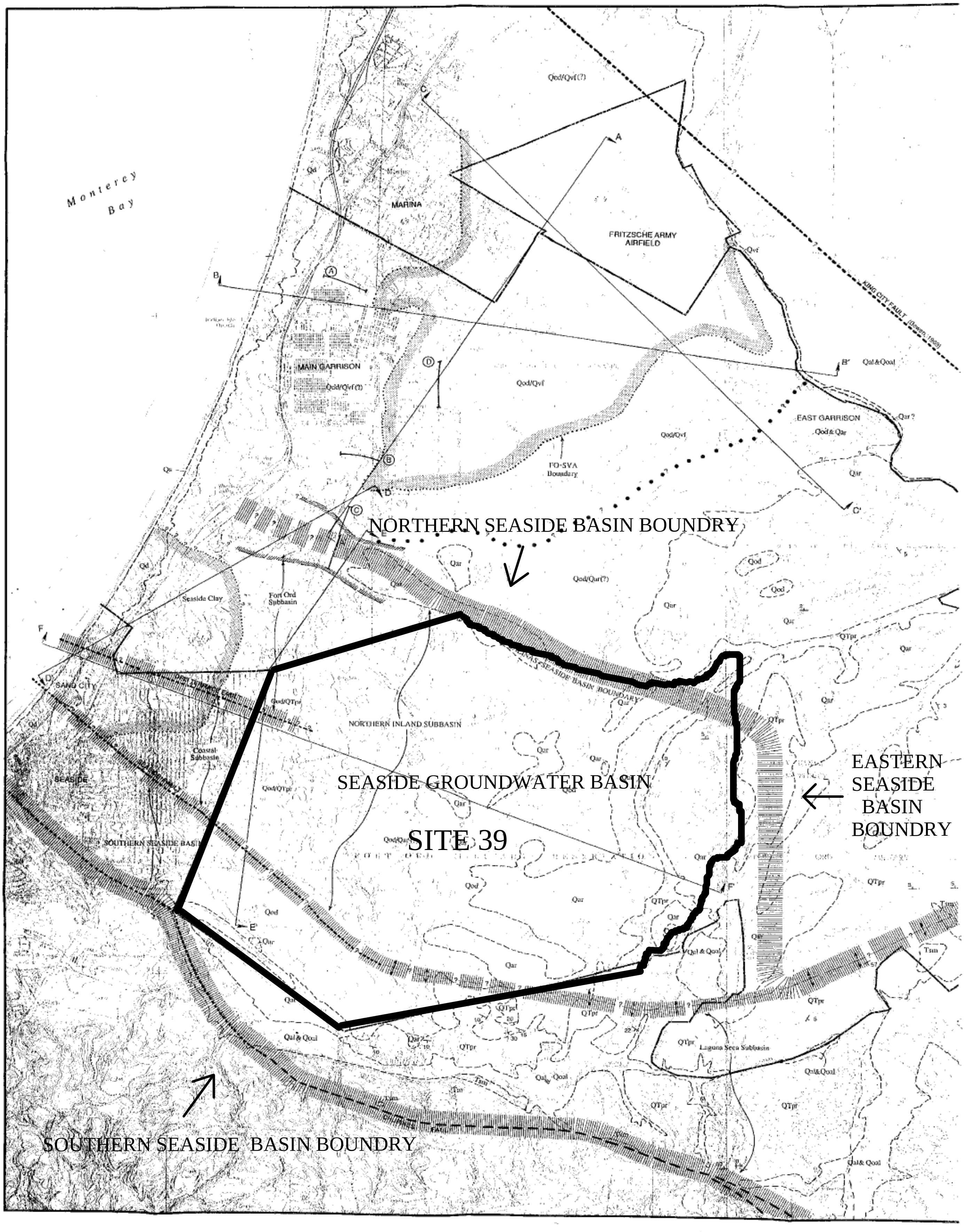
Note: Map generated from Fort Ord cleanup documents

Pesticide Sampling
Fort Ord RI/FS 1995, Vol II - Remedial Investigation
Basewide Background Soil Investigation
BW-1283E

Fort Ord Community Advisory Group (FOCAG) 7-6-2010

SEASIDE GROUNDWATER BASIN / SITE 39 IMPACT AREA

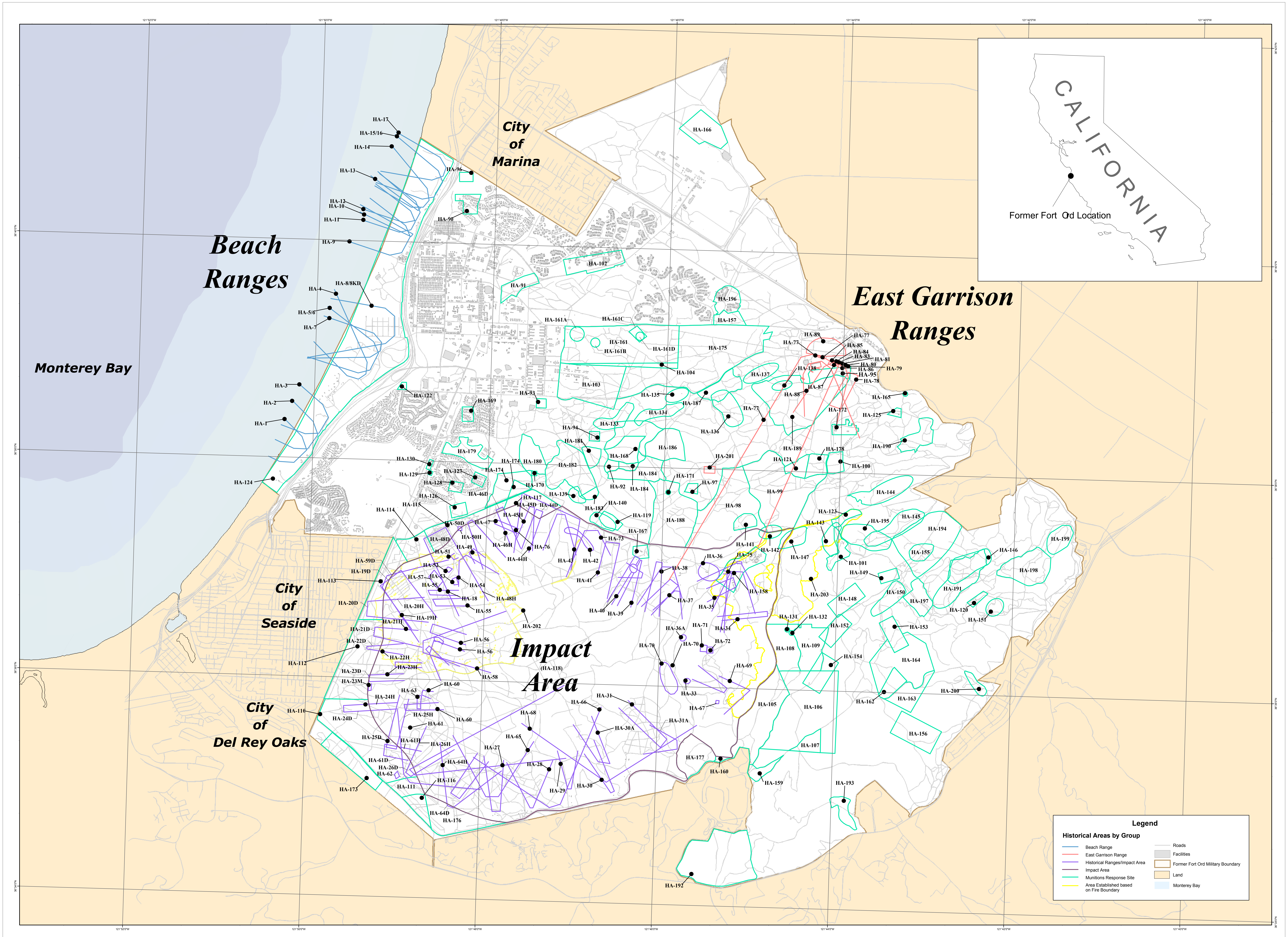
Basewide Hydrogeologic Characterization
BW-0608 PLATE 3



▬ SITE 39 BOUNDRY (8000 Acres, one of the countries largest munitions training areas.)

▥ SEASIDE GROUNDWATER BASIN BOUNDRY (Supplies City of Seaside drinking water.)

Where did all the munitions chemicals go? What chemicals where looked for? What where the actual chemical detection levels?



Fort_Ord_GIS - Plate_1_1_HA_categorization_by_group.mxd

NO.	DATE	REVISIONS	BY	CHK

DESIGNED:
DRAWN: JCF
APPROVED: BF
DATE: 11/2006

PROJECT NO: 4087040806 02A
SCALE: 1" = 1750'
CHECKED: WF
DATE: 11/2006

MACTEC

Historical Areas, Investigation Status

FORMER FORT ORD, CALIFORNIA

Historical Areas of the Former Fort Ord
Characterization of Historical Areas
by Group

PLATE 1.1
SHEET
REVISION NUMBER A
DATE