The Health Risk Assessment for Treatment of Energetic Wastes by Open Detonation at China Lake

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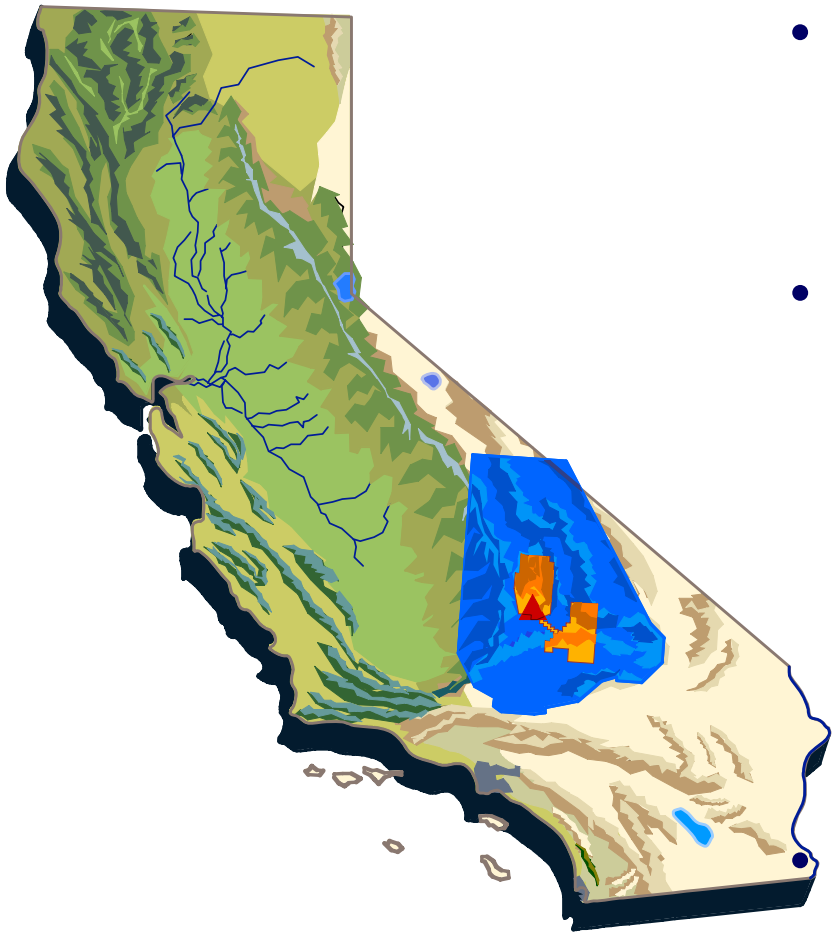
Participating Organizations

- **NAWCWD China Lake**
- **NAWS China Lake**
- **URS Corporation**
- **Chemical Compliance Systems, Inc.**

Main Topics

- **China Lake and its OD Facility**
- **Permitting and the Original Health Risk Assessment (HRA)**
- **Four Steps of the HRA**
- **HRA Results**
- **Tracking OB/OD Events**
- **Permit Limitations**

China Lake

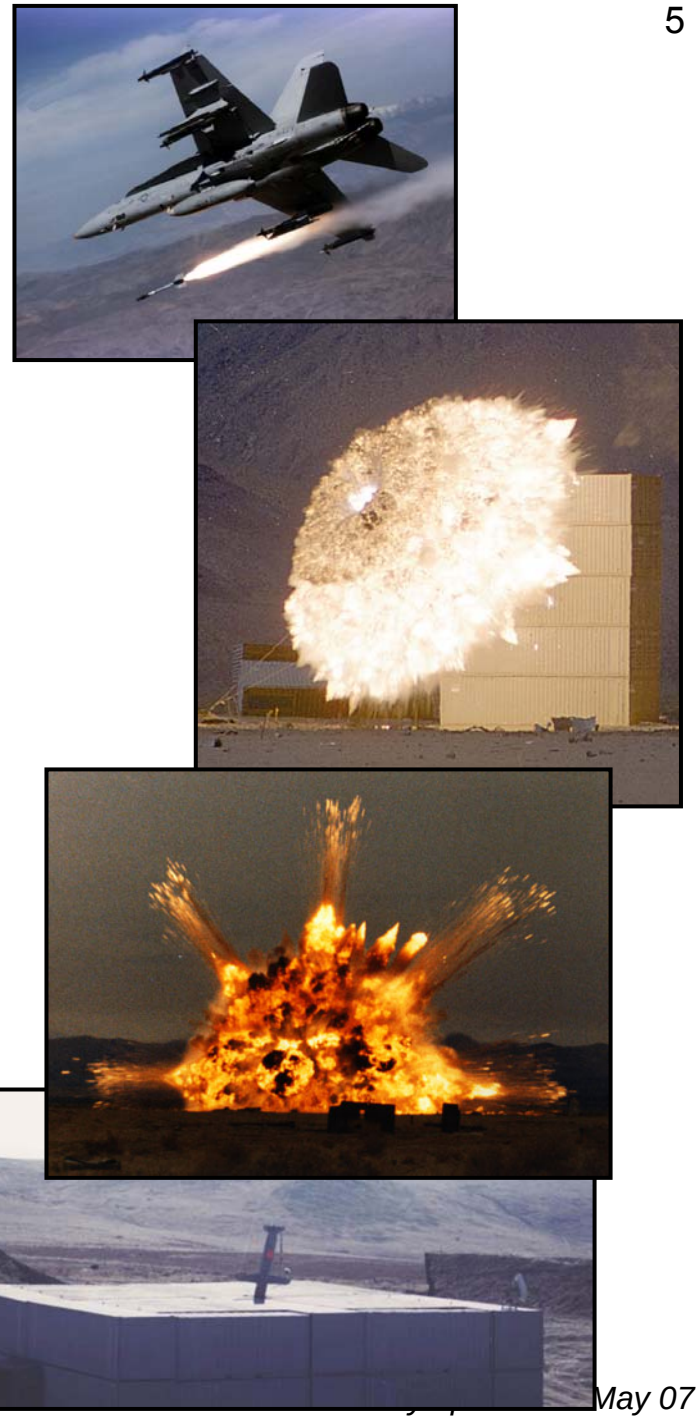


- **Located in Upper Mojave Desert**
  - **Arid climate**
  - **>330 clear days per year**
- **Navy's largest Research, Development, Test, & Evaluation (RDT&E) facility**
  - **<u>Land (orange):</u> 1,100,000 acres or 1700 square miles**
  - **<u>Airspace (blue)</u>: 12,500,000 acres or 19,600 square miles**
- **Minimal Encroachment**
  - **Little population growth**
  - **Mainly surrounded by BLM land**

China Lake Mission

- **RDT&E of weapons systems, software integration, and energetic materials**

- **In performing mission... Generate 100,000 to 300,000 pounds of energetic waste per year**
  - **Cannot transport off-CL**
  - **Must treat on-site**



Energetic Wastestreams Generated

Munitions

- Expired/Excessed (Standard Items)
- RDT&E (NonStandard Items)

Laboratory R&D

- Leftover scrap from mixes/casting
- Energetic-contaminated "trash" (e.g. rags, gloves)
- Samples
- Contaminated solvents

Current Method of Treatment

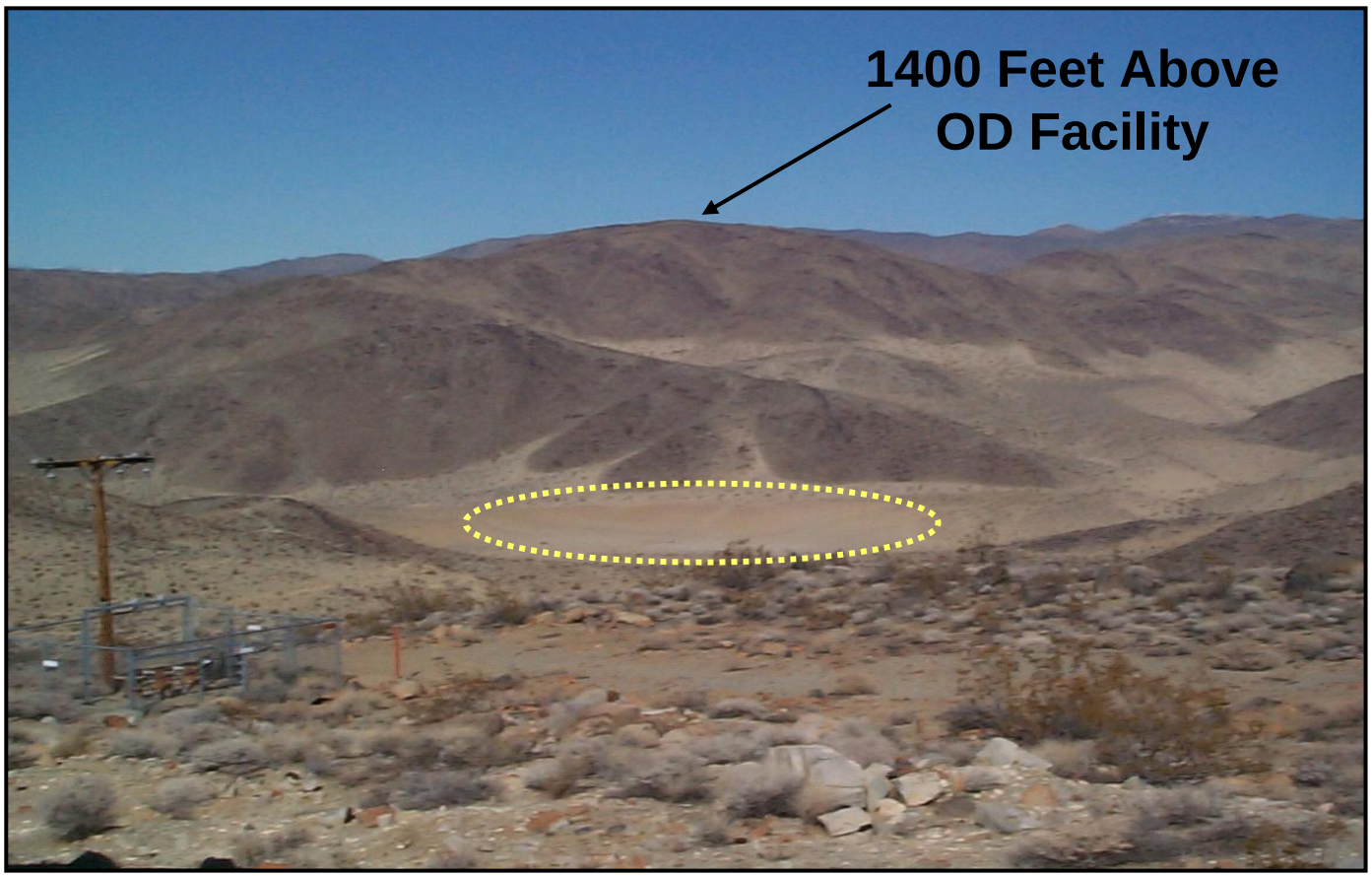
- **<u>Open Detonation</u> - Primary method of treatment**
  - **Rarely Open Burn; Last OB August 1998**
- **OD directly on ground (Waste is NOT buried)**
- **Range Limit = 15,000 lbs Explosive Weight**

View of OB/OD Facility

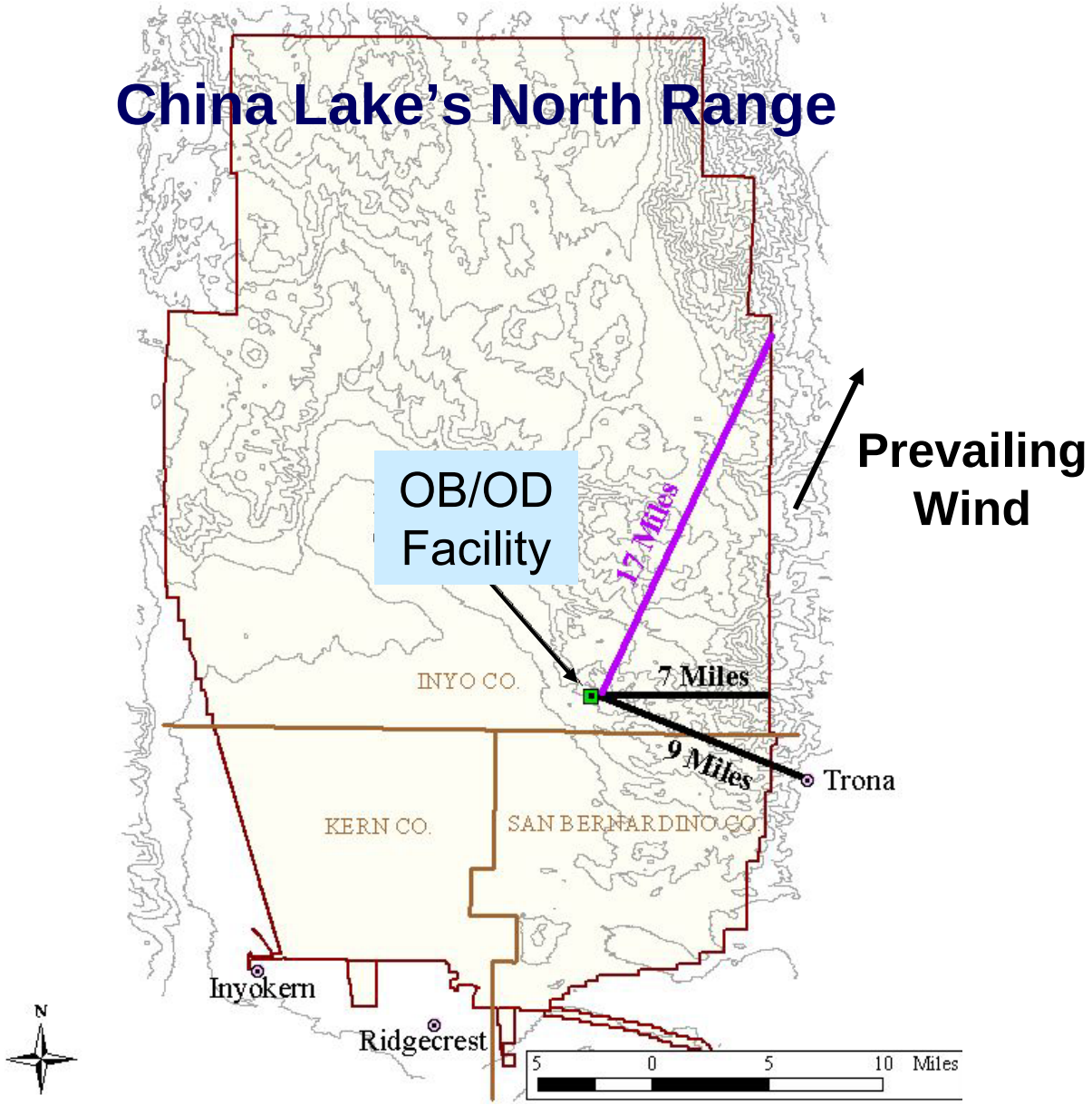
(One Mile to South & 700 Feet Above)

Arid & Mountainous

Depth to Groundwater is > 400 feet



OB/OD Facility Location



Permitting China Lake OB/OD Facility

- **Currently operates under:**
  - **RCRA (Hazardous Waste) Part A Interim Status Permit**
  - **Clean Air Act Title V Permit**

- **Permitting Requirements**
  - **Numerous**
  - **Human Health Risk Assessment (HRA)**

- **Preparation of original HRA started in early 1990s with direction from CA EPA**

Original HRA

Lack of Validated Data in early 1990s

+

Lack of Standardized Guidance

⬇

Use of Overly Conservative Assumptions

⬇

Inaccurately Inflated Health Risks

⬇

Severe Limitations in Annual & Event Treatment Quantities

Revisions to the Original HRA

- **With expertise from our technical codes, completed four major efforts:**
  1) **Emissions Factor (EF) Database**
  2) **Fate of Metals (casings & paints/coatings)**
  3) **Chamber Tests for OD of Explosive-Contaminated Wastes (ECW)**
  4) **Alternative Technology Assessment**

Copies of all reports are available!

- **New effort to address limited EFs for metals:**

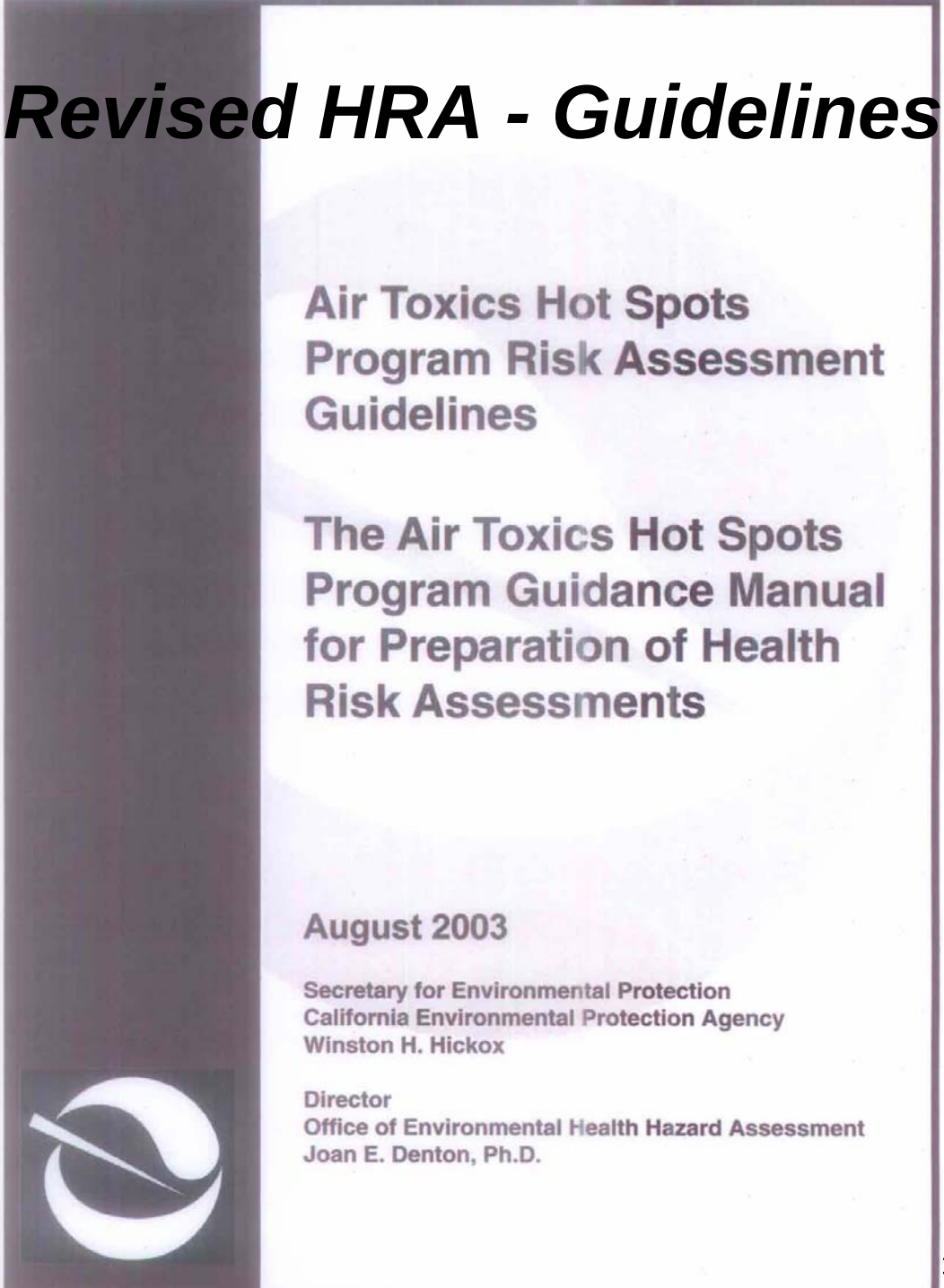
Presentation by Eric Gogley at end of this session: "Open Detonation: Metal Emissions – Phase 1"

Revisions to the Original HRA

Our New Approach

- **Science-based**
- **Technically accurate**
- **Data-driven**
- **Regulatory agencies support**

Revised HRA - Guidelines



Four Steps of the HRA

1) **Hazard Identification**
   - Identifies emission sources, chemicals that cause adverse health effects, & emission rates
2) **Exposure Assessment**
   - Predicts potential dose of emissions to the surrounding population through air dispersion modeling
3) **Dose-Response Assessment**
   - Describes expected human response to a level of exposure using toxicity factors for the chemicals of concern
4) **Risk Characterization**
   - Combines the results of Steps 2 & 3 to estimate potential for adverse health effects

Four Steps of the HRA

1) Hazard Identification

Identifies emission sources, chemicals that cause adverse health effects, & emission rates

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Predicts potential dose of emissions to the surrounding population through air dispersion modeling

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Combines the results of Steps 2 & 3 to estimate potential for adverse health effects

Emission Sources

DIRECT – Generated directly from the OB or OD event

- **Waste Items – OB & OD**

  - **Energetic Components**

  - **Nonenergetic Components**

Energetic-Contaminated Waste (ECW)

→ Packaging, rags, plastic, gloves, foil, etc contaminated with energetics

Munition Components

→ Circuitry found in guidance & control sections

Emission Sources

DIRECT – Generated directly from the OB or OD event

- **Fuel – OB Only**
  - **Wood**
  - **Diesel**
- **Crater Dust – OD only**

Emission Sources

INDIRECT – Generated from activities that support the waste treatment activities

- **Windblown dust – OB & OD**
- **Grading the OD facility soil**
- **Ash handling – OB only**

Chemicals of Concern
&
Emission Factors

See Backup Slides

FOUR STEPS of the HRA

1) Hazard Identification

Identifies emission sources, chemicals that cause adverse health effects, & emission rates

2) Exposure Assessment

Predicts potential dose of emissions to the surrounding population through air dispersion modeling

3) Dose-Response Assessment

Describes expected human response to a level of exposure using toxicity factors for the chemicals of concern

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Combines the results of Steps 2 & 3 to estimate potential for adverse health effects

Air Dispersion Models

OBODM (EPA 2003)

- **Stem & mushroom cloud (OD)**
- **OB Events**

→ **Used China Lake EFs, not library of EFs in OBODM**

Upper Level

Stem

Low Level

ISCST3

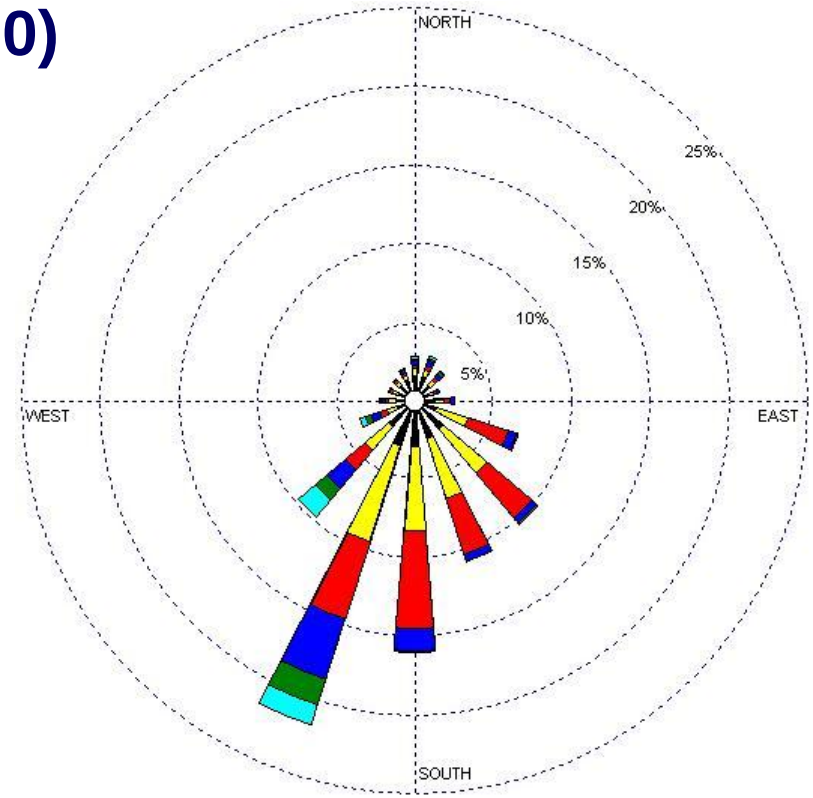
- **Low-level dust cloud (OD)**
- **Grading OD Facility Soil**
- **Ash handling (OB)**
- **Diesel & wood combustion (OB)**
- **Windblown dust (OD & OB)**

Plume Heights

- **Adjusted input parameters (fuel heat content, burn rate or time, emission strength) for both dispersion models until results represented conditions witnessed in the field**

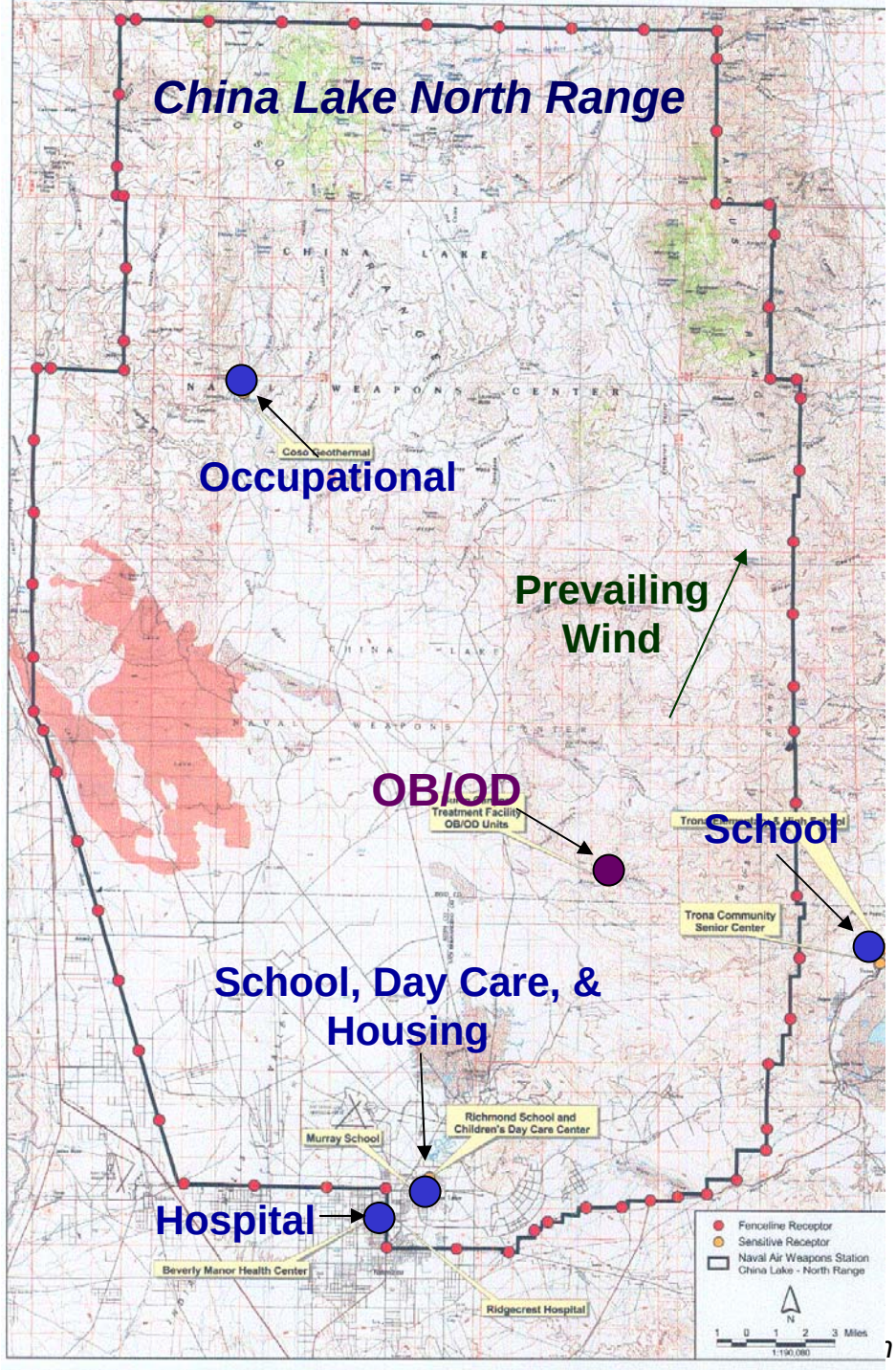
Meteorological Data

- **Met station located 1 mile south & 700 feet above the OB/OD facility**
- **Use 4 years of surface sequential hourly data**
- **Met data limited to when emissions typically occur (0900 to 1700)**



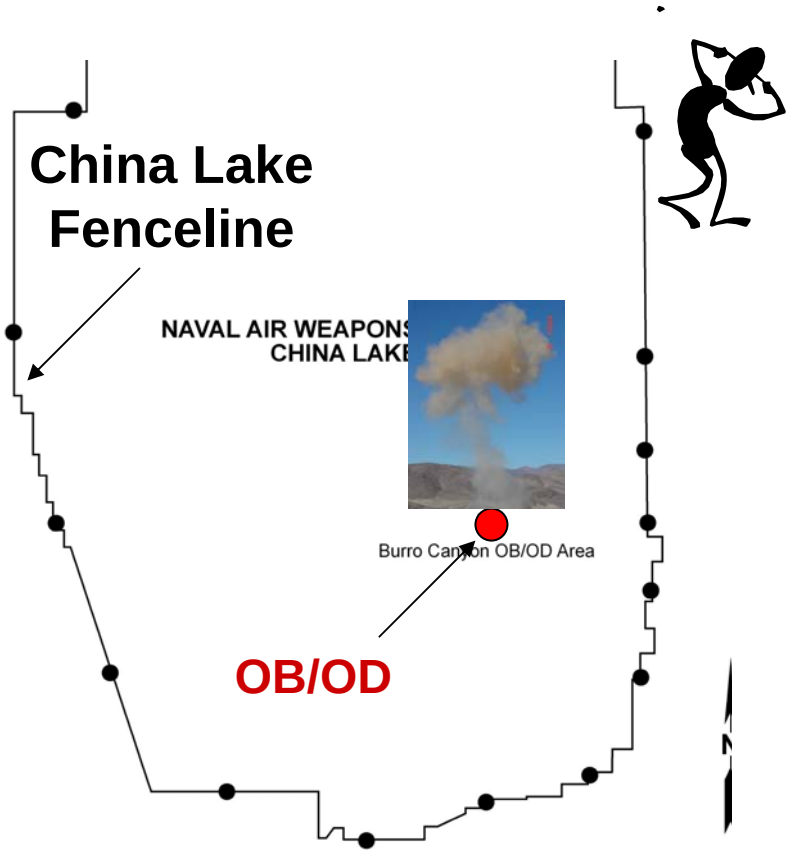
Receptors

- **66 at Fenceline:**
  Every 22.5 degrees
  Augmented with additional
- **Occupational**
  (on-Station)
- **Sensitive**
  (on & off-Station)



Exposure Routes

- **Inhalation, ingestion, dermal contact with soil, human milk ingestion by infants**
- **<u>Maximum Exposed Individual (MEI)</u> approach**



- **Continuous exposure**
- **Same fenceline location**
- **24 Hours/Day**
- **70 Years**
- **Residential scenario**

Actual risks are substantially lower!

FOUR STEPS of the HRA

1) Hazard Identification
   Identifies emission sources, chemicals that cause adverse health effects, & emission rates
2) Exposure Assessment
   Predicts potential dose of emissions to the surrounding population through air dispersion modeling
3) **Dose-Response Assessment**
   Describes expected human response to a level of exposure using toxicity factors for the chemicals of concern
4) Risk Characterization
   Combines the results of Steps 2 & 3 to estimate potential for adverse health effects

Toxicity Values

Used published toxicity values from five sources in a progressive manner chosen by regulatory agencies

1) **Air Toxic Hot Spots Program Risk Assessment Guidelines (2003)**
2) **Oak Ridge National Lab Risk Assessment Information System RAIS/IRIS (2003)**
3) **EPA Region 6 Human HRA Protocol for HW Combustion Facilities (1998)**
4) **Risk Assessment Guidance for Superfund (1995)**
5) **EPA Region 9 Preliminary Remediation Goals (2002 & 2004)**

Surrogate compounds used where no values exist!

FOUR STEPS of the HRA

1) Hazard Identification
   Identifies emission sources, chemicals that cause adverse health effects, & emission rates
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4) **Risk Characterization**
   Combines the results of Steps 2 & 3 to estimate potential for adverse health effects

Health Effect Categories

- **Lifetime risk of developing cancer**

  ANNUAL Regulatory Threshold =

  1 in one million at the MEI

- **Potential for chronic noncancer effects**

  ANNUAL Regulatory Threshold =

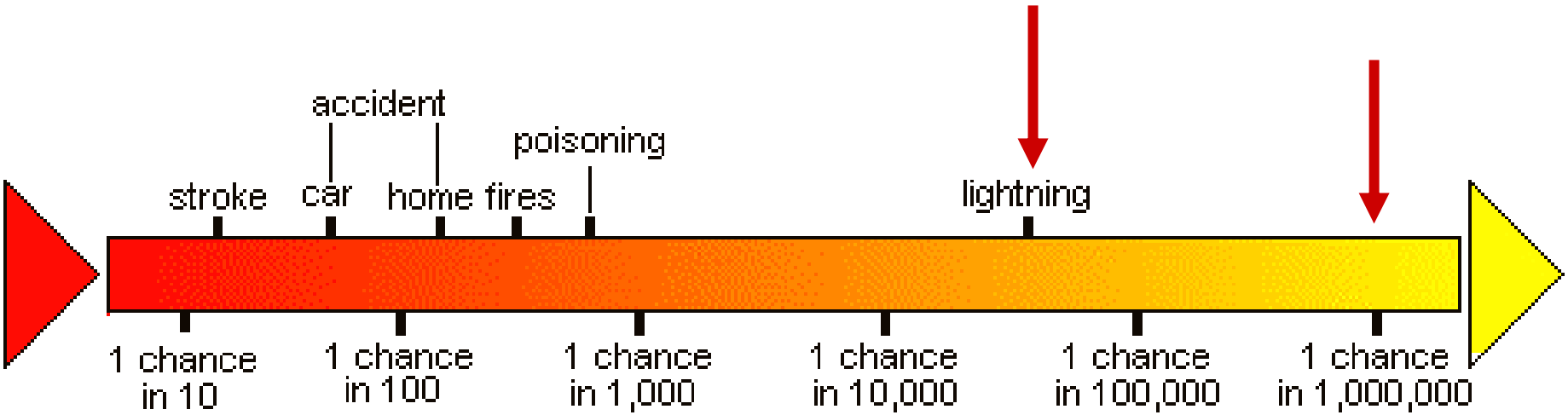
  Hazard Index (HI) of 1.0 at the MEI

- **Potential for acute noncancer effects**

  HOURLY Regulatory Threshold =

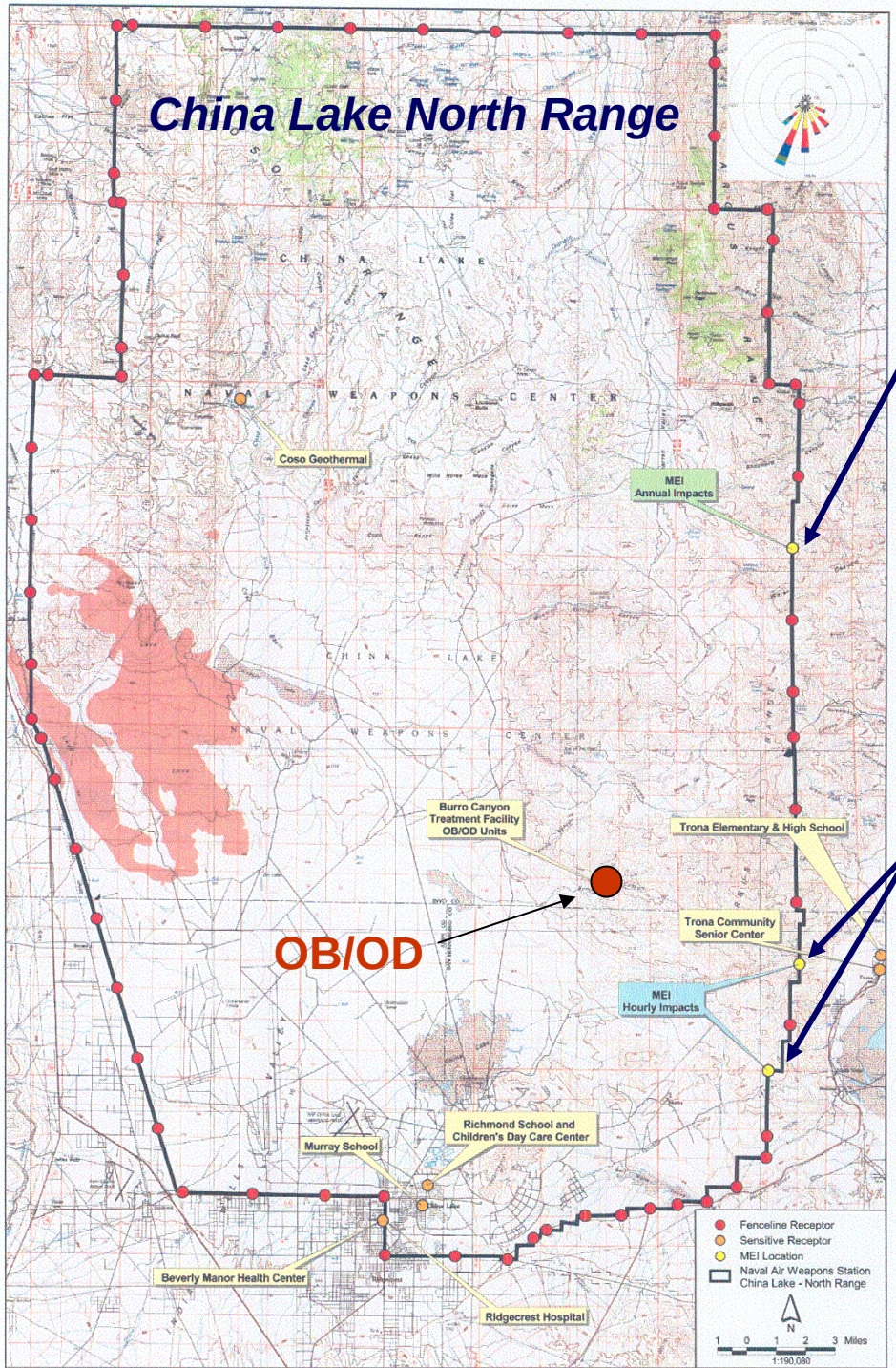
  HI of 1.0 at the MEI

Putting 1 in One Million Risk in Perspective



Greater risk of being hit by lightening than the annual regulatory threshold for cancer risk!!

Source: "Air Pollution & Health Risk" EPA Publication 450/3-90-022 (1991)



Location of MEIs

Long Term (70 year) MEI

- Cancer Risk
- Chronic Noncancer Effects

Uses one year average wind speed & direction that represents all 70 years

Short Term (Hourly) MEI

- Acute Noncancer Effects

Uses recorded worst-case wind speed & direction for any one hour during 0900 to 1700

*Possible ANNUAL Treatment Quantities of Waste Based on Health Effects **

OPEN DETONATION		
Highest Family	13,281,000 lbs/year	Triple-Base Gun Propellant
Lowest Family	544,000 lbs/year	Pyrotechnics
OPEN BURN		
Highest Family	2,727,000,000 lbs/year	TNT/Aluminum
Lowest Family	4,349,000 lbs/year	Single-Base Gun Propellant

*** Health effects from crater & windblown dust are included in each applicable family**

Possible HOURLY Treatment Quantities of Waste Based on Health Effects *

OPEN DETONATION		
Highest Family	8,504,000 lbs/hour	Double-Base Rocket/Missile Propellant w/out Pb
Lowest Family	16,000 lbs/hour	Double-Base Rocket/Missile Propellant with Pb
OPEN BURN		
Highest Family	30,257,000 lbs/hour	Double-Base Rocket/Missile Propellant w/out Pb
Lowest Family	15,000 lbs/hour	Double-Base Rocket/Missile Propellant with Pb

* **Health effects from crater & windblown dust are included in each applicable family**

Tracking OB/OD Events

SETUP TRACKING CATEGORIES

ENERGETIC WASTES

Use the energetic families from the EF analysis!

Melt Cast Explosives	
A1	TNT based (Comp-B, Cyclotol, Octol)
A2	TNT / Aluminum (H-6)
Plastic Bonded Explosives (PBXs)	
B1	Nitramine / binder
B2	Nitramine / binder / aluminum
B3	Nitramine / binder / aluminum / AP
Other Explosives	
C1	e.g. PbN3, ammonium picrate
Pyrotechnics (OD ONLY)	
P	Pyrotechnics

Gun Propellants	
IA	Single base (NC)
IB	Double base (NC / NG)
IC	Triple base (NC / NG / NQ)
Rocket/Missile Propellant	
IIA	Double base with lead
IIB	Double Base w/o Lead
IIC	AP / binder / Al
IID	AP / binder / Al / nitramines (>50% AP)
IIE	AP / binder reduced smoke
IIF	Nitramine/Energetic Binder/Al/ <20% AP

Tracking OB/OD Events

SETUP TRACKING CATEGORIES

NONENERGETIC WASTES

OB Only
Wood
Diesel
Ash Handling

OD Only
W = ECW
M = Munition Components

Grading OD Area

Tracking OB/OD Events

CHARACTERIZE EACH WASTE ITEM

→**Identify Waste Item Components**

- **Comprise the waste item**
- **Vary from one to many**
- **Both energetic & nonenergetic**

M-1 CHAIN
Paper Wrapper, Tetrytol, Det Cord Covering, & Det Cord PETN

COMP A-3
Cardboard Box, Plastic Bag, & Comp A-3

Tracking OB/OD Events

PLACE EACH COMPONENT IN A TRACKING CATEGORY

EXAMPLE

"PBXN-109 Explosive Scrap w/ Contaminated Rags & Plastic"

Gross weight (includes packaging) = 11 lbs

Explosive weight = 6 lbs

Component	Category	Amount (lbs)
PBXN-109	B2	6
Packaging & Contaminated rags & plastic	W (for ECW)	5

Tracking OB/OD Events

APPLY the EQUIVALENCY SYSTEM to the TRACKING CATEGORIES

- **To accommodate tracking the treatment of various types & quantities of waste generated from China Lake's RDT&E mission**

How Does It Work??

Note that each tracking category has annual & event permit limits…

Tracking OB/OD Events

APPLY the EQUIVALENCY SYSTEM to the TRACKING CATEGORIES

Treat the maximum quantity allowed by the permit annually (or hourly) for one category

OR fraction of the maximum quantity allowed by the permit annually (or hourly) for several different categories

Sum of all fractions (ratio of the actual quantity treated to the permitted quantity) cannot exceed 1.0 or 100%!

→ ***Hypothetical example included in the backup slides***

Permit Quantity Limiting Factors

- **FOUR factors limit the quantities of waste treated**
- **The permit sets these quantities**

1) Health Effects from the HRA

2) Air Quality Standards

   Criteria pollutants (Federal & State)

   Both daily & annual limits

3) Explosive Safety

   Each OD event ≤15,000 lbs of energetics only

   Each OB event ≤1000 lbs of energetics only

   No annual safety limits

Permit Quantity Limitations

4) Logistics - Based on available range time, available EOD staff, CL's varying wastestream, time for event setup (daylight only), & "Burn Day" designation

ANNUAL	**OD**	***Average* of 1 15,000 lb Event/Day = 5,475,000 lbs/year**
	OB	***Average* of 1 1,000 lb Event/Day = 365,000 lbs/year**
HOURLY	**OD**	**30,000 lbs/Hr (energetic AND nonenergetic categories)**
	OB	**2,000 lbs/Hr (energetic AND nonenergetic categories)**

The factor with the lowest quantity is used in the permit!

ANNUAL Permit Quantity Limitations

	# of TRACKING CATEGORIES			
LIMITING FACTORS	Health Effects	Air Quality	Explosive Safety	Logistics
OD	6*	0	N/A	12
OB	0	0	N/A	18

*** Cancer effects from cadmium in metal casings**

HOURLY Permit Quantity Limitations

	# of TRACKING CATEGORIES			
LIMITING FACTORS	Health Effects	Air Quality	Explosive Safety	Logistics
OD	0	2*	0	16**
OB	0	0	0	18

*** Crater dust**

**** Note that the logistics factor is also limited by the safety factor of 15,000 lbs/event of energetics**

Conclusions

- China Lake's revised HRA approach is science-based, data-driven, technically accurate AND developed with participation from the regulatory agencies
- Health risks from the revised HRA are several orders of magnitude lower than the original HRA
- Using the MEI scenario, actual risks are much lower
- Logistics is the biggest limiting factor for permit quantities, NOT health risks
- Tracking equivalency system allows for operating flexibility

BACK-UP SLIDES

Direct Emissions – Energetic Wastes

Evaluation Process Started with Huge Matrix of Emission Factor (EF) Data

EF Data from Over 100 Tests →

~1000 Compounds

↓

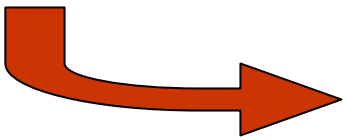
CHEMNAME	TEST OD-1 CompB Bulk	TEST OD-2 Exp.D Bulk	TEST OD-3 RDX Bulk	TEST OD-4 TNT Bulk Surface OD	TEST OD-5 TNT 10-m AGL OD	TEST OD-6 20mm HEI Cart.	TEST OD-7 40mm HEI Cart.
	A1	C1	B1	A1	A1	IIA	B1
Acenaphthylene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Acetaldehyde	a	a	a	a	a	0.00E+00	0.00E+00
Acetic Acid	a	a	a	a	a	0.00E+00	0.00E+00
Acetone	a	a	a	a	a	0.00E+00	0.00E+00
Acetonitrile	a	a	a	a	a	0.00E+00	0.00E+00
Acetophenone	a	a	a	a	a	0.00E+00	0.00E+00
Acetylene	a	a	a	a	a	1.80E-04	4.20E-05
Acrolein	a	a	a	a	a	0.00E+00	0.00E+00
Acrylonitrile	a	a	a	a	a	0.00E+00	0.00E+00
Allyl Chloride	a	a	a	a	a	0.00E+00	0.00E+00
Aluminum	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E-04	1.50E-02
Amino-2,6-Dinitrotoluene,4-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amino-4,6-Dinitrotoluene,2-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Antimony	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Barium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Refer to: "Emissions from the Energetic Component of Energetic Wastes During Treatment by OD", NAWCWD China Lake, June 2005

Direct Emissions – Energetic Wastes

TO SIMPLIFY:

1) **Eliminated chemicals… e.g. duplicates, those not formed from OBOD**
2) **Eliminated tests… e.g. waste buried, water-suppressed**



Reduced to over 500 compounds & 44 tests

3) **Validated EF data… e.g. Eliminated contaminated samples, correct for background levels**
4) **Evaluated the compounds by:**
   Health risk AND Available test data
5) **Provided surrogate chemicals for those compounds with a health risk but without EF data**

Direct Emissions – Energetic Wastes

6) **Each set of EF test data placed into one of 16 energetic families indicative of our wastes**
   - ***Emissions within a family are similar because the family's constituents are similar***

Melt Cast Explosives	
A1	TNT based (Comp-B, Cyclotol, Octol)
A2	TNT / Aluminum (H-6)
Plastic Bonded Explosives (PBXs)	
B1	Nitramine / binder
B2	Nitramine / binder / aluminum
B3	Nitramine / binder / aluminum / AP
Other Explosives	
C1	e.g. PbN3, ammonium picrate
Pyrotechnics	
P	Pyrotechnics

Gun Propellants	
IA	Single base (NC)
IB	Double base (NC / NG)
IC	Triple base (NC / NG / NQ)
Rocket/Missile Propellant	
IIA	Double base with lead
IIB	Double Base w/o Lead
IIC	AP / binder / Al
IID	AP / binder / Al / nitramines (>50% AP)
IIE	AP / binder reduced smoke
IIF	Nitramine/Energetic Binder/Al/ <20% AP

Direct Emissions – Energetic Wastes

7) Combined OB and OD EF test data
8) For the 3 families* without EF test data, chose surrogate families
9) Used maximum EFs for each compound from all of the tests in each family

Melt Cast Explosives	
A1	TNT based (Comp-B, Cyclotol, Octol)
A2	TNT / Aluminum (H-6)
Plastic Bonded Explosives (PBXs)	
B1	Nitramine / binder
B2	Nitramine / binder / aluminum*
B3	Nitramine / binder / aluminum / AP*
Other Explosives	
C1	e.g. PbN3, ammonium picrate
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IIC	AP / binder / Al
IID	AP / binder / Al / nitramines (>50% AP)*
IIE	AP / binder reduced smoke
IIF	Nitramine/Energetic Binder/Al/ <20% AP

Direct Emissions – NonEnergetic Wastes

EXPLOSIVE-CONTAMINATED WASTE (ECW)

- Rags, gloves, plastic, aluminum foil, packaging, etc. contaminated with energetics
- Mainly from R&D lab activities
- No EF test data for OD of ECW
- Small-scale chamber tests conducted at China Lake

- Tests designed to maximize dioxin formation

Refer to: "Open Detonation Simulation Tests for Explosive-Contaminated Waste", Nov 2003

Contd – Direct Emissions – NonEnergetic Wastes

EXPLOSIVE-CONTAMINATED WASTE (ECW)

Dioxin EFs – China Lake Tests

Species	Comp A-3 Donor EF	ECW EF	Original HRA*
TEQ as 2,3,7,8-TCDD	1.6e-13	2.0e-11	2.2e-8

Because of higher temperatures from the AP…
OD of ECW is cleaner than OD of donor…
except for dioxins!

**** From medical waste incinerator model***

Direct Emissions – NonEnergetic Wastes

MUNITION COMPONENTS

- Circuitry found in the guidance & control sections
- Difficult to determine accurately
- Use EFs from ECW tests
- For treatment of each “all-up” munition, use the weight from older Sparrow missile with lots of circuitry = 212 lbs

Direct Emissions – Fuel for OBs

WOOD

EFs for residential fireplaces from EPA's AP-42 Section 1.9

DIESEL FUEL

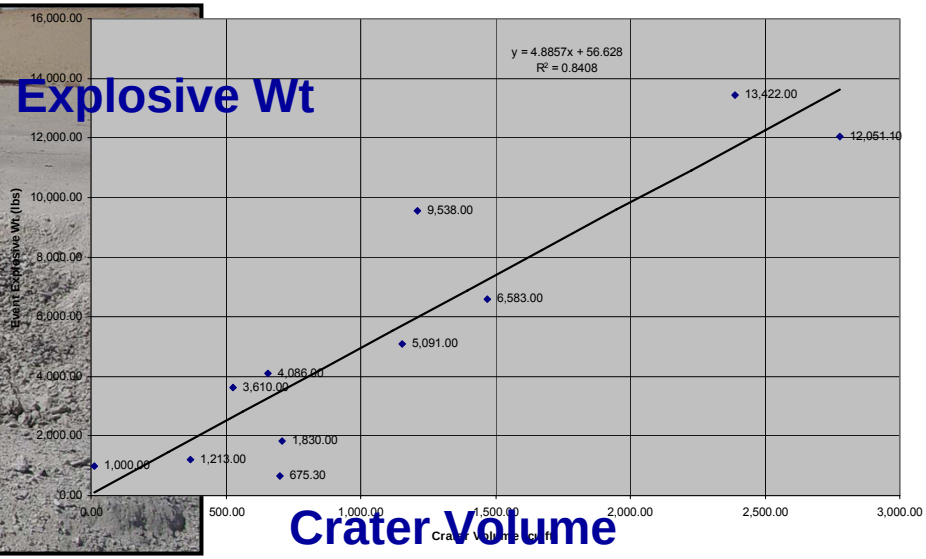
Diesel Particulate Matter – EFs from Source Test Report for Open Burn Simulator, URS, Jan 2000 (JP-5 EF)

Toxics – EFs from Ventura County APCD 2001

Direct Emissions

DUST EMISSIONS from OD CRATER

- Measured volume of several craters
- Plotted Explosive Wt vs Crater Volume
- For PM_{10} & $PM_{2.5}$ emissions, analyzed soil samples for particle size distribution
- For toxic compounds, used actual soil sample data



Indirect Emissions

WINDBLOWN DUST (OB & OD)

- **Used 39 acres… includes sides of canyon & disturbed area**
- **For PM_{10} and $PM_{2.5}$ emissions, use "Windblown Dust from Unpaved Roads" Almanac Emission Projection Data by EIC, CARB 2005 (Section 7.13 – Updated Aug 1997)**
- **For toxic compounds, use actual soil sample data**

Indirect Emissions

DUST FROM GRADING

- **Used 5.5 acres of disturbed area for 1 event in 1 hour**
- **For PM_{10} and $PM_{2.5}$ emissions, use EPA AP-42 EFs for heavy construction, Section 11.9**
- **For toxic compounds use actual soil sample data**

Indirect Emissions

ASH HANDLING (OB Only)

- **For PM-10 & PM-2.5 EFs, use Mechanical Handling of Ash from EPA's AP-42 (Section 13.2.4)**
- **Toxic compounds – Analytical results of ash**

Contributions to Cancer Risk

	OB	OD
Primary Pathways	**Inhalation**	**Inhalation** **Dermal** **Soil Ingestion**
Primary Chemicals	**Benzidene** **1,3-Butadiene** **7,12-Dimethylbenz(a)anthracene,** **3,3-Dimethybenzidine** **RDX**	**Arsenic** **Cadmium**

Contributions to Chronic Noncancer HI

	OB	OD
Target Organ	Eye Skin Respiratory System	Eye Skin Respiratory System
Primary Chemicals	Acrolein Aluminum Ammonia Arsenic Benzene Chlorine DEHP Dimethyamine Hydrogen Chloride Hydrogen Cyanide Silica	Aluminum Arsenic Cadmium Chlorine Manganese

Contributions to Acute Noncancer HI

	OB	OD
Target Organ	Alimentary Tract Eye Kidney Skin Respiratory System	Alimentary Tract Eye Kidney Skin Respiratory System
Primary Chemicals	Arsenic Chlorine Copper Hydrogen Chloride Hydrogen Cyanide Nitrogen Dioxide	Arsenic Benzene Copper Chlorine Hydrogen Chloride Hydrogen Cyanide Nitrogen Dioxide

TRACKING – Hypothetical Example of Equivalency System

Category	Permit Limits		Amount Treated	Used for Event	Used Annually
	Hour	Annual			
EVENT 1					
A	100	5000	10	10%	0.2%
B	200	8000	110	55%	1.3%
C	300	10,000	70	23%	0.7%
Totals for Event 1				**88%**	**2.2%**
EVENT 2					
A	100	5000	20	20%	0.4%
B	200	8000	50	25%	0.6%
C	300	10,000	150	50%	0.2%
Totals for Event 2				**95%**	**1.2%**
EVENT 3					
A	100	5000	5	5%	0.1%
B	200	8000	40	20%	0.5%
C	300	10,000	100	33%	1.0%
Totals for Event 3				**58%**	**1.6%**

Each event is < 100%

Annual = 2.2% + 1.2% + 1.6% = 5% (<100%)