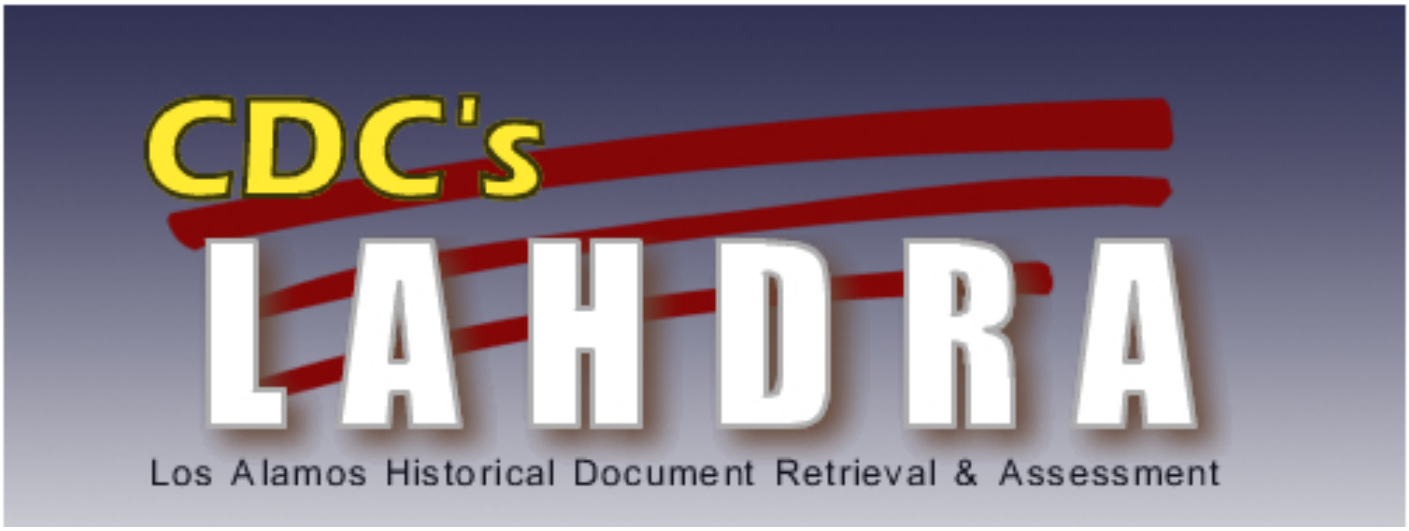

Final Report of the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) Project

Prepared for the Centers for Disease Control and Prevention (CDC)
National Center for Environmental Health
Division of Environmental Hazards and Health Effects
Radiation Studies Branch

November 2010

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Prepared as a team effort by individuals from:
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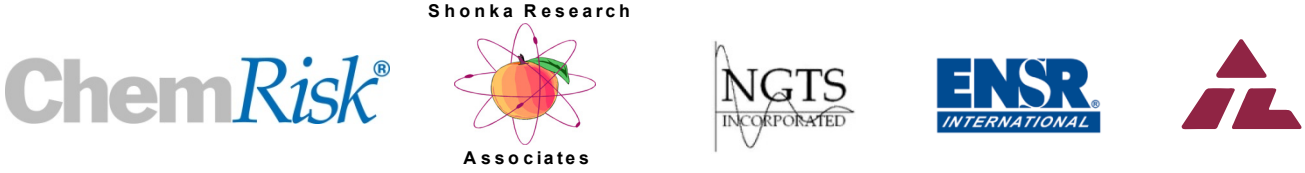
November 2010



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Dedication

This report is published in special memory of Thomas Widner, Project Director and Principal Author for the LAHDRA project, who passed away during the completion of this report. Mr. Widner spent the last 28 years of his career becoming an authority in health physics, environmental dose reconstruction, industrial hygiene, and human health risk assessment, and made significant contributions to these fields. He was instrumental in developing and advancing our understanding of retrospective dose reconstruction at former DOE weapons complex sites.

Mr. Widner was an intelligent, compassionate individual who will be remembered as a respected colleague, mentor, and friend by the LAHDRA team. Without his scientific contribution and dedication to this project, this report would have not been possible.

Community Introduction to the LAHDRA Report

The following poem was written by Beata Tsosie-Peña of Santa Clara Pueblo and read at the LAHDRA public meeting held January 28, 2010 at Ohkay Owingeh Pueblo, New Mexico. The LAHDRA team selected this poem for inclusion in this report because it reflects an example of a community member's perspective.*

The LAHDRA team would like to express its appreciation to the communities surrounding Los Alamos National Laboratory for its active involvement in this project over the last decade.

Dedicated to the women of Las Mujeres Hablan, and those working for justice in their communities, with special thanks, to Tina Cordova (Tularosa Basin Downwinders Consortium)

Growing up I was disconnected
Some things were not discussed
Among people who valued hard work and employment
One-sided silence through years of schooling
I learned about the nuclear age
From movies and propaganda and Bradbury field trips
The glorified versions of a history that happened in my own back yard
In our state of Enchantment
Pristine open spaces and a population
Not respected by a higher nation
Still living off the land as the industrial age passed them by
Only to get thrust into nuclear realization
Beneath a mission
Urgent and thick with intensity
Beneath a shroud of secrecy

I was not yet born
The day scientists feared for our sky
Thoughts of atmospheric ignition
And that everyone would die
I was not yet born when the Jemez was taken
Homesteaders relocated, not of their volition
Uranium miners on the road to perdition
Beloved mountains, occupied before I could praise them
Disconnected from ancestral knowledge
In three generations
Clan animals vanished
Even as the jobs began to appear
Unprotected hired hands from the valley
A job was nothing to fear
It was a welcome exchange in hard times

I wasn't yet born
The day silver ash rained down for days
And a plume of poison drifted over state lines
Radioactive fallout, on cisterns of drinking water
On crops and livestock, who all miscarried that year
The people were lied to
And went about life as usual
While the truth fled
With bread over their mouths
To keep from breathing air they knew was foul
And the world was changed forever
A month later, 80,000 people were killed instantly
Justified atrocity named enemy
And the book was closed on Trinity
Even though it was our own citizens who were bombed
Children born into an experimental population
With a cancer rate way higher than the average nation
Entire families still sick and dying
Still crying, for the elders and children they lost too soon

I – was born into military healthcare, mixed blood and desert beauty
Free from the shame of colonized blame
My grandfather employed by Sandia
My down-winder grandmothers who birthed babies and taught me songs
While washing tainted laundry and making pots from local clay
I wonder now, can earth decay?
Eating the elk my uncles brought down
Breathing fire smoke from trees that drank
From discarded waste placed…anyplace

Today – my daughters are born
Into single driver car twice daily parades
Dependence on industrial weapon economic charades
The sound of bombs exploding
As we pray to the sun in mornings
Will my cornmeal prayers
Protect them as they play in ditches
Carrying water from a source three miles away from tritium releases?
What did my oldest get exposed to?
As I breathed in smoke from a tech area burned 3 times over
What kind of poison
Can penetrate the walls of my womb?
What stories were silenced, and why, and from whom?

The truth must be told
From the people who lived it
Who dwell in this place that houses our spirit
Respectfully, I pray, for past, present and future souls to be at peace someday
For clean earth, air and water
So my children can play

Splashing and laughing as we tend to our gardens
Beneath the loving gaze of our sacred mountains
Free of fear from invisible poison
Free to hear, undisturbed and clear, the birds sing in the morning
As we continue to question
And speak our points of view

Let us share the stories anew that have never been told
And release the pain not even a century old
No longer shamed by accusations of ignorance
Let our diverse voices be our deliverance
No breath here is unimportant
We are free to pray
Each in our way
For justice, strong leaders, and supportive institutions
A foundation for our expectations
As we welcome in this time of healing
For the good
Of all future generations

Beata is from Santa Clara Pueblo and works for environmental health and justice with Tewa Women United, a network of Las Mujeres Hablan.

*This poem was selected as an example of one community member's perspective; it may not reflect the perspective of the community as a whole. The perspectives and opinions expressed within the poem do not necessarily state or reflect the views of the Centers for Disease Control and Prevention or the authors of this report.

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LAHDRA PROJECT

LIST OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

25	Early code name for uranium-235; (from the isotope's atomic number (9**2**) and atomic weight (23**5**)
28	Early code name for uranium-238; (from the isotope's atomic number (9**2**) and atomic weight (23**8**)
37	Early code name for neptunium-237 (from the isotope's atomic number (9**3**) and atomic weight (23**7**)
49	Early code name for plutonium-239 (from the isotope's atomic number (9**4**) and atomic weight (23**9**)
410	Early code name for plutonium-240 (from the isotope's atomic number (9**4**) and atomic weight (240); i.e., one higher than 23**9**, hence the **10**)
ACIS	Automated Chemical Inventory System
ADWEM	Associate Laboratory Directorate for Nuclear Weapons Engineering and Manufacturing—formerly ALDNW
AEC	U.S. Atomic Energy Commission (DOE predecessor agency)
AIRNET	A LANL network of ambient air sampling stations
AKA	"also known as"
ALDNW	Former Office of Associate Laboratory Directorate for Nuclear Weapons
ANP	Aircraft Nuclear Propulsion
ARF	Atmospheric Release Fraction
ATSDR	Agency for Toxic Substances and Disease Registry
BR Site	Bruns Railhead Site (in Santa Fe, NM)
BZ	Breathing Zone
CAS	Chemical Abstracts Service, a registry for chemicals
Case	Early code word for curie, especially when referring to polonium shipments ("200 cases of Postum" meant 200 curies of polonium).
CBD	Chronic Beryllium Disease
cc	Cubic Centimeters
CCNS	Concerned Citizens for Nuclear Safety
Cd	Cadmium
CDC	Centers for Disease Control and Prevention
CEARP	Comprehensive Environmental Assessment and Response Program
CEDE	Committed Effective Dose Equivalent, a unit of radiation dose
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
Ci	Curie, a unit of radioactivity; 1 Ci = 3.7×10^{10} disintegrations per second.
CIC	Former Computing, Information and Communications (CIC) Division, now the Computing, Communications, and Networking Division (CCN)
CM	Chemistry and Metallurgy
CMB	Former Chemistry/Metallurgy/Baker Division, which later became MST Division
CMR	Chemistry and Metallurgical Research
CMR-12	The radiochemistry group at early LASL
CO_2	Carbon dioxide

DARHT	Dual-Axis Radiographic Hydrodynamics Test
D-Building	Earliest plutonium processing facilities at Los Alamos
DE	Dose Equivalent, a unit of radiation dose
D&D	Decontamination and Decommissioning
DF Site	Detonator Firing Site
DOE	U.S. Department of Energy
DOEAL	Department of Energy Albuquerque Operations Office
DOP	diocthyl phthalate, an aerosol often used to test effluent treatment filters
DP	DP Site[1], or TA-21.The site of plutonium processing at LANL from 1945 until 1978. Was also the site of polonium processing.
DPM	Disintegrations Per Minute, a rate of radioactive decay
DSF	Document Summary Form
DU	Depleted Uranium
DVD	Digital Versatile Disc
DX	Dynamic Experiments Division at LANL
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EIS	Environmental Impact Statement
EMAD	Engine Maintenance and Disassembly building at NRDS.
EMF	ElectroMagnetic Field
EML	Environmental Measurements Laboratory
ENSR	ENSR Corporation, a provider of ENvironmental SeRvices
ER	Environmental Restoration
ERDA	Energy Research and Development Administration (DOE predecessor agency)
ERSS	Environment and Remediation Support Services
ESA	Engineering Science and Application
ES&H	Environment, Safety, and Health
eV	Electron Volts
FACA	Federal Advisory Committee Act
fCi	Femtocurie, 10^{-15} curie, or 0.000000000000001 Ci
FGI	Foreign Government Information
FQ	Filter Queens- vacuum cleaners adapted at LASL to collect air samples
G-2	Army Intelligence
G/MAP	Gaseous Mixed Activation Products,
GMX	GMX Division (possibly for **G**adgets, **M**unitions, and E**x**plosives)
GMX-1	The Radiography Group at early LANL
GPS	Global Positioning System
GT Site	Anchor Site West
H	H Division or Health Division at LANL
HAI	History Associates Inc.
H-Division	The Health Division at LANL
HE	High Explosive
HEPA	High Efficiency Particulate Air filter
HHS	Dept of Health and Human Services
HMX	High Melting Explosive
HP Site	Hot Point Site
HSE	Health, Safety, and Environment

[1] There are several theories about the origin of the "DP Site" name for TA-21. It may stand for D-Prime, since it replaced D Building, "D Plant," "Displaced Persons," "D-Plutonium or "D-Production" (Martin 1998).

HSR	Health, Safety, and Radiation Protection group at LANL, formerly ESH
HT	Heat Treatment Building at TA-1
HTML	Hyper Text Markup Language
HTO	Tritiated water, water in which a hydrogen atom is replaced with tritium, ^{3}H
HSPT	Human Studies Project Team
HYPO	Water Boiler Reactor in its high-power configuration
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IH	Industrial Hygiene
IM-5	The Records Management Group within the LANL Information Management Division
INEEL	Idaho National Engineering and Environmental Laboratory
IP	Internet Protocol
IPM	Images per minute
JHSPH	Johns Hopkins School of Public Health
kW	kilowatt, one thousand watts of power
LA–	A prefix in many Los Alamos technical report designators
LAHDRA	Los Alamos Historical Document Retrieval and Assessment project
LALP	A type of LANL publication, from Los Alamos Laboratory publication
LAMS	A type of Los Alamos technical report, from Los Alamos Manuscript
LAMPF	Los Alamos Meson Physics Facility
LAMPRE	Los Alamos Molten Plutonium Reactor Experiment
LANL	Los Alamos National Laboratory (name from January, 1981 to present; formerly known as Los Alamos Scientific Laboratory January, 1947 to December, 1980.)
LANSCE	Los Alamos Neutron Science Center- formerly LAMPF
LA-PR	A type of Los Alamos technical report, from Los Alamos Progress Report
LAPRE	Los Alamos Power Reactor Experiment
LAPRE I	First Los Alamos Power Reactor Experiment
LAPRE II	Second Los Alamos Power Reactor Experiment
LA- UR	A type of Los Alamos technical report, from Los Alamos Unlimited Release
LCLS	LANL's Legal Counsel Litigation Support Database
LMFBR	Liquid Metal Fast Breeder Reactor
LOAEL	Lowest Observed Adverse Effect Level
LOPO	Water Boiler Reactor in its low-power configuration
LSSS	Limiting Safety System Setting
mA-hr	Millampere-hours, a measure of work load for accelerators like at LANSCE
MAP	Mixed Activation Products
MDL	Minimum Detection Level
MED	Manhattan Engineer District
MeV	Million Electron Volts
MFP	Mixed Fission Products
mL	milliliter, one thousandth of a liter
mm	millimeter, one thousandth of a meter
MDA	Minimum Detectable Activity
MOU	Memorandum of Understanding
MPC	Maximum Permissible Concentration
MST	Materials Science and Technology Division
MTR	Materials Test Reactor

MW	Megawatt, one million watts of power
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards (predecessor to NIST)
NCEH	National Center for Environmental Health, part of CDC
NCRP	National Council on Radiation Protection and Measurements
NEPA	Nuclear Energy for the Propulsion of Aircraft (a USAF project)
NERVA	Nuclear Engine for Rocket Vehicle Application
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NIOSH	National Institute for Occupational Safety and Health
NMED	New Mexico Environmental Department
NMT	Nuclear Materials Technology
NOAEL	No Observed Adverse Effect level
NO_x	Oxides of nitrogen
NRC	U.S. Nuclear Regulatory Commission
NRDS	Nuclear Rocket Development Station (at NTS)
NSA	Nuclear Science Abstracts
NTK	Need-to-know
NTS	Nevada Test Site
OCR	Optical Character Recognition
ORNL	Oak Ridge National Laboratory
ORF	Overall Release Fraction
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
OSR	Off-Site Releases Database
OSTI	Office of Scientific and Technical Information
OUO	Official Use Only
OWR	Omega West Reactor
OWREX	Omega West Reactor Experiment
PARKA	A Phoebus 1 reactor set up as a critical assembly
PBX	Plastic Bonded Explosive
PCB	Polychlorinated Biphenyls
PDF	Portable Document Format
PEL	Permissible Exposure Limit
PETN	pentaerythritol tetranitrate, an explosive
PHERMEX	Pulsed High-Energy Radiation Machine Emitting X-rays
PI	Priority Index
Postum	Early code word for polonium, a material used at Los Alamos.
PPM	Pages Per Minute

PROJECTS

Project Apple	Rocky Flats Plant
Project Camel	The first full-scale test firing of the "Fat Man" type bomb (minus the plutonium) at the China Lake Naval Ordnance Sta. in CA.
Project Orange	Pantex Plant
Project Royal	*unknown*
Project Sugar	Burlington Army Ordnance Plant in Iowa
Project Tee	*unknown*

PRG	Preliminary Remediation Goals
PRS	Potential Release Sites

PSR	Proton Storage Ring
P/VAP	Particulate Various Activation Products
Q	The top level of security clearance granted by DOE
R	Roentgen, a unit of radiation exposure
RAEHP	Rio Arriba Environmental Health Partnership
RaLa	Radioactive Lanthanum
RCRA	Resource Conservation and Recovery Act
RDX	Rapid detonating explosive
rem	A unit of radiation dose equivalent, from Roentgen Equivalent Man
RF	Respirable Fraction
RfC	Reference Concentration
RFETS	Rocky Flats Environmental Technology Site
RFI	RCRA Facility Investigation
RMAD	Reactor Maintenance, Assembly, and Disassembly building at NRDS.
RMC	Records Management Center
RPF	Records Processing Facility
RRES	Risk Reduction and Environmental Stewardship
RSAC	Radiological Safety Analysis Computer program
RSB	CDC's Radiation Studies Branch
S Site	TA-16; S is from Sawmill Site, after a former sawmill in the area.
S-7	LANL's Classification Office
SAP	Special Access Program
SCI	Sensitive Compartmented Information
SED	Special Engineering Detachment, in the Manhattan District era
SL-1	A 3-MW experimental reactor in Idaho, Stationary Low-Power Plant No. 1, that was destroyed in 1961 when a control rod was removed manually.
SM	South Mesa
SNM	Special Nuclear Material
SNPO	Space Nuclear Propulsion Office, a joint office between the AEC and NASA.
Soda Pulp	Early code name for bismuth, which was irradiated to make polonium.
SRA	Shonka Research Associates, Inc.
SRS	Savannah River Site
SUPO	Water Boiler Reactor in its highest (Super) power configuration
SWMU	Solid Waste Management Unit
TA	Technical Area; a section of land at Los Alamos, with TA number from 0 to 74,that has been the site of identified operations or activities
TATB	1,3,5-triamino-2,4,6-trinitrobenzene, an explosive
TD Site	Trap Door Site
TFF	Target Fabrication Facility
TLD	ThermoLuminescent Dosimeter
TNT	Trinitrotoluene, an explosive
TR	Transfer Record
TR	Trinity Project
TRU	Transuranic, that is elements having atomic numbers greater than 92
TSTA	Tritium Systems Test Assembly
TU	Tuballoy, an early code name for depleted uranium (from the British Tube Alloys project, a code name for their atomic bomb program)

UC	University of California, operator of the Los Alamos facility since its founding
UCNI	Unclassified Controlled Nuclear Information
UHTREX	Ultra High-Temperature Reactor Experiment
UK	United Kingdom
UNM	University of New Mexico
USAEC	United States Atomic Energy Commission
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VHS	Video Home System, a video cassette format patented by JVC
Vitamin B	Early code name for the isotope boron-10, a material used at Los Alamos.
VJ Day	The day of Allied victory over Japan in WW II
VRS	Virtual ReScan technology
VTR	Vault Type Room
W	Site W, the Hanford Plant near Richland, Washington
W-47	Code designation for Wendover Air Base in Utah that was the training site of the 509th Composite Group, which dropped the atomic bombs over Japan.
WB	whole body
WEM	Weapons Engineering and Manufacturing
WETF	Weapons Engineering Tritium Facility (at TA-16)
WFO	Work for Others
WIPP	Waste Isolation Pilot Plant
WNR	Weapons Neutron Research Facility
WP	Weapons Physics
WX	Weapons Group WX
X-10	The X-10 Site in Oak Ridge, Tennessee; now Oak Ridge National Laboratory
Y	Site Y, the code name for Los Alamos Laboratory under the MED from April 1943 to December 1946.
Z	Z Division (named for Jerrold R. Zacharias, a physicist from MIT's Radiation Laboratory), an ordnance design, testing, and assembly group formed at LASL in July, 1945. Moved to the old Oxnard Air Field, east of Kirtland Air Base, just outside of Albuquerque between fall of 1945 and January, 1947 and became informally known as Sandia Base.

Reference: Martin 1998. Martin, C. *Los Alamos Place Names*. Los Alamos Historical Society, Los Alamos, New Mexico.

Metric (SI) Prefixes

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{18}	Exa	E	10^{-1}	Deci	d
10^{15}	peta	P	10^{-2}	Centi	c
10^{12}	tera	T	10^{-3}	Milli	m
10^{9}	giga	G	10^{-6}	Micro	μ
10^{6}	mega	M	10^{-9}	Nano	n
10^{3}	kilo	k	10^{-12}	Pico	p
10^{2}	hecto	h	10^{-15}	Femto	f
10^{1}	deka	da	10^{-18}	Atto	a

Summary of New and Old Radiological Units

Quantity	Name	Symbol	In other units
radioactivity	becquerel	Bq	1 disintegrations per second (dps)
(*old)*	curie	Ci	3.7×10^{10} Bq
absorbed dose gray		Gy	joule/kilogram (J/kg)
(*old)*	rad	rad	10^{-2} Gy
dose equivalent sievert		Sv	J/kg
(*old)*	rem	rem	10^{-2} Sv
exposure	coulomb per kilogram	C/kg	
(old)	roentgen	R	2.58×10^{-4} C/kg

Chemical Concentrations

1.0 mg/L = 0.001 g/L = 1,000 µg/L = 1,000,000 ng/L

1.0 µg/L = 0.001 mg/L = 1,000 ng/L

1.0 ng/L = 0.001 µg/L = 0.000001 mg/L

1.0 percent = 1.0 g/100g = 10 ^{o}/oo (parts per thousand) = 10 g/kg = 10,000 mg/kg

1.0 g/kg = 0.10 percent = 1,000 mg/kg

1.0 mg/kg = 0.0010 g/kg = 0.00010 percent = 1,000 µg/kg

1.0 µg/kg = 0.001 mg/kg = 1,000 ng/kg

Table of the Elements

Z #*	Name	Symbol
89	Actinium	Ac
13	Aluminum	Al
95	Americium	Am
51	Antimony	Sb
18	Argon	Ar
33	Arsenic	As
85	Astatine	At
56	Barium	Ba
97	Berkelium	Bk
4	Beryllium	Be
83	Bismuth	Bi
107	Bohrium	Bh
5	Boron	B
35	Bromine	Br
48	Cadmium	Cd
20	Calcium	Ca
98	Californium	Cf
6	Carbon	C
58	Cerium	Ce
55	Cesium	Cs
17	Chlorine	Cl
24	Chromium	Cr
27	Cobalt	Co
29	Copper	Cu
96	Curium	Cm
105	Dubnium	Db
66	Dysprosium	Dy
99	Einsteinium	Es
68	Erbium	Er
63	Europium	Eu
100	Fermium	Fm
9	Fluorine	F
87	Francium	Fr
64	Gadolinium	Gd
31	Gallium	Ga
32	Germanium	Ge
79	Gold	Au
72	Hafnium	Hf
108	Hassium	Hs
2	Helium	He
67	Holmium	Ho
1	Hydrogen	H
49	Indium	In
53	Iodine	I
77	Iridium	Ir
26	Iron	Fe
36	Krypton	Kr
57	Lanthanum	La
103	Lawrencium	Lr
82	Lead	Pb
3	Lithium	Li
71	Lutetium	Lu

Z #	Name	Symbol
12	Magnesium	Mg
25	Manganese	Mn
101	Mendelevium	Md
80	Mercury	Hg
42	Molybdenum	Mo
60	Neodymium	Nd
10	Neon	Ne
93	Neptunium	Np
28	Nickel	Ni
41	Niobium	Nb
7	Nitrogen	N
102	Nobelium	No
76	Osmium	Os
8	Oxygen	O
46	Palladium	Pd
15	Phosphorus	P
78	Platinum	Pt
94	Plutonium	Pu
84	Polonium	Po
19	Potassium	K
59	Praseodymium	Pr
61	Promethium	Pm
91	Protactinium	Pa
88	Radium	Ra
86	Radon	Rn
75	Rhenium	Re
45	Rhodium	Rh
37	Rubidium	Rb
44	Ruthenium	Ru
104	Rutherfordium	Rf
62	Samarium	Sm
21	Scandium	Sc
106	Seaborgium	Sg
34	Selenium	Se
14	Silicon	Si
47	Silver	Ag
11	Sodium	Na
38	Strontium	Sr
16	Sulfur	S
73	Tantalum	Ta
43	Technetium	Tc
52	Tellurium	Te
65	Terbium	Tb
81	Thallium	Tl
90	Thorium	Th
69	Thulium	Tm
50	Tin	Sn
22	Titanium	Ti
74	Tungsten	W
92	Uranium	U
23	Vanadium	V

Z #	Name	Symbol
70	Ytterbium	Yb
39	Yttrium	Y
30	Zinc	Zn
40	Zirconium	Zr

*The Z Number, or Atomic Number, of an element is the number of protons in its atomic nucleus.

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Executive Summary

The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project began in early 1999. It was conducted by the Centers for Disease Control and Prevention (CDC), with much of the work performed by contractors to CDC, namely ChemRisk, LLC and subcontractors Shonka Research Associates, Inc., NGTS, Inc., ENSR Corporation, Advanced Technologies and Laboratories International, Inc., and several individual consultants. The LAHDRA project's primary purpose was to identify all available information concerning past releases of radionuclides and chemicals from the Los Alamos National Laboratory (LANL). Originally established as "Site Y" as part of the Manhattan Project to create the first atomic weapons, LANL's activities expanded after the War to include thermonuclear weapon design, high explosives development and testing, weapons safety, nuclear reactor research, waste disposal and incineration, chemistry, criticality experimentation, tritium handling, biophysics, and radiobiology.

This report presents a summary of the information obtained by the LAHDRA team regarding:

- historical operations at LANL;
- the materials that were used;
- the materials that were likely released off site;
- development of residential areas in Los Alamos; and
- the relative importance of identified releases in terms of potential health risks.

The information in this report was obtained from millions of records reviewed at LANL by the project team, books and reports that are publicly available, and interviews with past and current LANL workers and members of the public.

Products of the LAHDRA Project

The products of the LAHDRA project include:

- this report, which summarizes historical operations and prioritizes associated releases;
- a project information database containing bibliographic information and content summaries of relevant documents located by the project team;

- sets of copies of documents selected as relevant by the project team, made available in a reading room in Albuquerque, NM;

- a collection of electronic document images, saved as Portable Document Format (PDF) files, of all documents for which paper copies or electronic files were obtained; and

- a chronology of incidents and off-normal events identified in report reviews prepared by the LANL Health Division.

Systematic Document Reviews Conducted

LAHDRA document analysts had unprecedented access for an independent study team reviewing historical records at LANL. A core group of approximately 15 analysts, most of whom held U.S. Department of Energy (DOE) Q-level security clearances, worked on the project on a part-time basis. As originally specified, the LAHDRA project was divided into six phases that were planned to be completed sequentially. Each phase was meant to target a specific group of records, as outlined below:

Phase 1: The LANL Records Management Center

Phase 2: The LANL Archives

Phase 3: The LANL Technical Report Library

Phase 4: Records at the LANL Technical Areas

Phase 5: Records pertaining to "Work for Others"

Phase 6: Documents located at other sites

Because of restrictions that were placed on the number of analysts that could work in a given repository at any time, the sequential approach was abandoned and work progressed in multiple repositories concurrently. The systematic document searches that were performed by the LAHDRA team are described in Chapter 3. The main elements of the information gathering process are summarized in Table ES-1 along with approximations of the quantities of documents reviewed at each repository.

Table ES-1. Summary of LAHDRA systematic document review efforts at Los Alamos

Location	Approximate Quantities Reviewed	Documents (or Groups of Documents) Selected and Summarized
LANL Records Center	16,896 boxes of documents; 18,000 rolls of microfilm; 31,420 notebooks	2,902
LANL Reports Collection	3,085 classified reports by LANL and 32,000 by others; 10,000 unclassified LANL reports in vault and 25,000 online; 90,000 unclassified reports by other plus 600,000 on microfiche	1,529
ES&H Records Center and satellites	1,187 boxes of documents plus dosimetry and air quality records	227
LANL Archives	1,532 archived collections, with 125,000 folders	992
Litigation Support Database	75,724 documents by title; 3,813 full documents	347
LANSCE Division	10,000 documents by title and 2,500 full documents in Admin. Building; 3,375 documents in Radiological Air Monitoring Archive	36; 97
WEM / WP Divisions	18,876 documents and 1,126 photos in vault; 36 safes containing 7,056 documents	2
Engineering Drawings Center	2,550 drawings on aperture cards plus ~1,000 reels of microfilm	188 and ~1,000 drawings
Environmental Stewardship Division	250,000 documents from the ERSS database; 137 boxes of NEPA/EA records; 12 drawers of EIS documents; ~100 Cultural Resources reports	1,056
Industrial Hygiene & Safety Records	8 lateral file drawers of historical records	17
Former J Division (Field Testing)	699 boxes with approximately 11,000 folders	0

Notes: ES&H = Environment, Safety, and Health; LANSCE = Los Alamos Neutron Science Center; WEM = Weapons Engineering and Manufacturing; WEP = Weapons Engineering and Physics; ERSS = Environment & Remediation Support Services; NEPA = National Environmental Policy Act; EA = Environmental Assessment; EIS = Environmental Impact Statement.

LANL Central Records Management Center

The initial and principal focus of LAHDRA's document review effort was the LANL Central Records Management Center. The Central Records Center was a 15,000 square foot building located at 180 6th Street in Los Alamos. Its purpose was to receive and catalogue records from the various LANL groups and divisions, to place and maintain these records in retrievable storage, and disposition them in accordance with DOE retention and disposition guidelines and other associated requirements (such as the moratorium on destroying records deemed pertinent to epidemiological studies). Late in the project, the Central Records Center was relocated to the new National Security Sciences Building (NSSB) at Technical Area (TA)-3. Systematic review of the contents of the Central Records Center that were accessioned prior to December 31, 1999 was completed in early June, 2005, with all of the selected

material received from LANL by the end of that month. During late 2008 and continuing into 2009, the project team reviewed records accessioned by the Records Center since 1999.

LANL Archives Collections

During the first calendar quarter of 2005, LAHDRA analysts began reviewing printouts of LANL Archives collections and the folders existing within each collection, identifying (based on reviewing folder titles) folders to be reviewed by the project team. The project team began the reviewing records at the LANL Archives in early June, 2005, and completed this review in early May, 2006. During late 2008 and continuing into 2009, the project team reviewed collections added to the LANL Archives since 2005.

LANL Reports Collection

From 1942 to 1992, the LANL Reports Collection was a filing point for reports issued by LANL and by other DOE sites. Three types of records are in the Report Collection vault, which is located below the LANL Research Library in the Oppenheimer Study Center building at TA-3: classified reports in paper format, unclassified reports in paper format, and reports on microfiche. Approximately 3,000 classified report titles issued by LANL as LA- or LAMS- reports are located in the Report Collection. In the second half of the project, the project team was denied access to the following categories of classified information in document repositories at LANL:

- Nuclear weapons design information,
- Information falling under Sigma levels 14 and 15,
- Sensitive Compartmented Information (SCI),
- Special Access Programs (SAPs),
- Foreign Government Information (FGI), and
- Unclassified Sensitive Vendor Proprietary Information.

Access to classified reports issued by any of the following entities with publication dates after 1962 was denied beginning in March, 2001: LANL, Lawrence Livermore National Laboratory, Sandia National Laboratory, the Defense Nuclear Agency and its predecessor and successor agencies, and the DOE Albuquerque Area Office. Prior to this ban, approximately 55-60% of the classified LANL-issued technical reports had been reviewed. Approximately 1,144 classified LANL reports issued after 1962 were not initially reviewed by the project team because of LANL's March, 2001 decision to withhold

them. LAHDRA document analysts were allowed to review the titles of these withheld reports, but that approach proved to be ineffective and problematic because of the vagueness of many titles. During 2005, C.M. Wood of the CDC reviewed the titles of LANL technical reports that fell within this restriction, and selected 18 for review. These classified technical reports were reviewed by a LAHDRA document analyst, and several were selected as relevant, summarized, and added to the project information database.

The LAHDRA team reviewed all of the classified "LA" and "LAMS"-series reports issued before 1963 in the Report Collection. . Access to classified reports issued by entities other than LANL has been denied to LAHDRA analysts since November, 2001. The project team had reviewed approximately 35-40% of the classified reports issued by entities other than LANL (up to letter "L" in the alphabetically-shelved documents) prior to losing access. The remaining reports in this group were reviewed during 2005 by a LAHDRA analyst working in tandem with an LANL employee trained to recognize deniable category information.

Approximately 10,000 unclassified report titles issued by LANL as LA- or LAMS- reports are located in the Report Collection vault. Images of approximately 25,000 unclassified LA-, LA-MS-, LA-UR, and LA-PR reports are available as PDF files in the LANL electronic library catalog. Prior to the heightened security measures that followed the terrorist attacks of September 11, 2001; the unclassified "LA" reports were publicly available on the LANL Web site. The project team reviewed 100% of the unclassified "LA" reports that were formerly available without restriction on the Internet.

The Report Collection vault also holds approximately 90,000 unclassified reports issued by academic institutions, private corporations that conducted research on behalf of DOE, DOE sites other than LANL, and other defense-related agencies. The project team reviewed 70 to 75% of these non-LANL unclassified reports shelved in the Report Collection vault (up to letter "P" in the alphabetically shelved documents) before work was halted in 2004, and the remainder were reviewed early in 2007. There are also approximately 1.5 million documents on microfiche at the LANL Reports Collection. A search of two relevant databases indicated that LANL is the authoring institution for approximately 11,000 NSA reports and 53,000 DOE Energy reports, or about 10% of each database's contents. The project team completed reviewing these microfiche reports in November, 2006.

ES&H Records Center

The ES&H Records Center has been in operation since 1998. Its purpose is to receive records from the various ES&H Groups, catalogue and consolidate those records, and to eventually forward them on to the LANL Central Records Center. Many of the records stored at the ES&H Records Center are recent (i.e., from the 1990s). A total of 1,187 boxes were reviewed in the ES&H Records Center. Of these, 227 were

deemed to contain material relevant to the project. In early 2009, LAHDRA analysts reviewed records that had been added to the ES&H collection since their previous review of those holdings.

The LAHDRA team also completed reviews of the Weapons Engineering and Manufacturing (WEM) and Weapons Physics (WP) division holdings. These LANL divisions are organized under the Directorate's Office of the Associate Laboratory Directorate for Nuclear Weapons Engineering and Manufacturing (ADWEM), formerly known as the Office of Associate Laboratory Directorate for Nuclear Weapons (ALDNW). The WEM/WP vault-type room (VTR) contained approximately 18,876 classified documents and 1,126 classified photographs. Thirty-six classified safes within the ADWEM main offices were also reviewed for potentially relevant information. The safes contained 7,056 documents marked "RESTRICTED DATA," but LAHDRA analysts did not identify any titles considered potentially relevant to the LAHDRA project. After reviewing a list of classified vaults and repositories at LANL, the LAHDRA team estimated the holdings at 21 vaults, 107 VTRs, 5 alarmed rooms, and 1,600 repositories (file cabinets, 2-5 drawers each, with combination locks). Not all of the vaults or VTRs contain only records; some contain weapon parts and/or special nuclear material.

Los Alamos Neutron Science Center

Document review of the Los Alamos Neutron Science Center (LANSCE Division, formerly known as the Los Alamos Meson Physics Facility, or LAMPF) focused on office files within Main Administration Building 1 located at TA-53 and the Radiological Air Monitoring (RAM) Records Archive. Of these documents, 2,500 were considered potentially relevant and underwent detailed review. Copies of 36 documents were requested and summarized for the LAHDRA project database. Highlights of these records are the Shift Supervisor Logbooks that contain daily beam current and beam-hour information dating back to 1971. Forty-five boxes of documents (3,375 documents) located at the RAM Records Archive (Building 3R) were reviewed. Copies of 97 documents were requested and summarized. This archive would be a source of relevant information for any future studies of off-site releases from TA-53.

Legal Counsel Litigation Support Database

During the LAHDRA project, team members made several attempts to gain access to the contents of the Legal Counsel Litigation Support Database (LCLS), sometimes called the Legal Database. While the database itself was not made available, in late 2003/early 2004 the LAHDRA team received and reviewed a hardcopy listing of the documents contained in that database. The list includes document number, title, author, addressee and copy recipient, date, status, and page count. The LCLS database consists of the following document categories: H-Division, Human Studies Project Team, Central Records Management, "Other" documents, and Records Processing Facility documents. During 2005, LAHDRA analysts

reviewed the hardcopy indices of the LCLS database and selected documents for review. Images of these documents were made available to LAHDRA analysts by Legal Counsel Staff, and they were reviewed between May and September, 2005. Documents selected as relevant were printed and released to the project team.

LANL Engineering Drawings Facility

In February, 2006, the project team began reviewing documents held by the LANL Engineering Drawings Facility at TA-63. This facility housed engineering drawings and associated documents (memos, letters, specifications, etc.) dating back to the 1940s. The initial searching was for drawings pertinent to Original TA buildings (especially D-Building), Omega Site facilities and associated stacks, DP Site facilities and ventilation systems, and the Los Alamos town site. Approximately 1,000 historical drawings were selected as relevant to the LAHDRA project. The project team also completed systematic review of the TA-63 microfilm records, which contain correspondence and documents pertaining to many LANL facility modifications.

Environmental Restoration Records Processing Facility

LAHDRA analysts reviewed the holdings of a small library of environmental restoration related documents at both TA-21 and the Environmental Restoration (ER) group's Records Processing Facility (RPF). The TA-21 library was housed in a portable building at DP West Site; its purpose was to serve as a resource for individuals involved in decommissioning activities there. Its holdings included binders of memoranda, remediation investigation reports, and drawings. Much of this material had already been collected by the project team during its review activities in the Records Center and elsewhere. The RPF managed the records of what was formerly the ER group at LANL. Most of the holdings of the LANL Records Processing Facility, located at the Pueblo School Complex, had been scanned to PDF files, and were available to review through an electronic document management utility called Domino. Review of this material is discussed below. In addition to these electronic records, the project team also reviewed some hardcopy records that existed at the RPF earlier in the project, as well as records that had recently been acquired and not yet scanned.

Environmental Stewardship Division

As the project team completed its systematic review activities for LANL's centralized records collections, it shifted its focus to records held within division or group offices. The initial focus of the review of division and group records was the Environmental Stewardship (ENV) Division. The ENV Division consisted of a large number of groups, many of which held records of interest to the project

team. Review of these records was therefore a substantial part of the team's activities as reviews at the centralized collections began winding down. Project team members also met with representatives of the following other LANL divisions and groups to inquire about their activities and any records they held:

- Associate Directorate for Security and Safeguards
- Chemistry
- Dynamic and Energetic Materials
- Earth and Environmental Science
- Environmental Protection
- Hydrodynamic Experiments
- Industrial Hygiene and Safety
- Materials Science and Technology
- Plutonium Manufacturing and Technology
- Radiation Protection
- Weapons Component Manufacturing
- Weapons Engineering Technology

LANL ENV Division

In May, 2006, the LAHDRA team obtained a summary of records and databases generated by the groups and programs within the LANL ENV Division. There were approximately 50 groups and programs listed, along with a number of electronic databases. Of the document collections and other information sources identified within the ENV Division, the largest by far was the RPF's Domino database. The Domino database was an electronic storehouse for historical and current RPF records (that is, environmental restoration files). These records included environmental project case files, remediation management records, regulatory compliance records, and decontamination and decommissioning records. The records were stored as PDF files and managed using the IBM Lotus Domino application. Records in the Domino application were indexed using a unique identifier known as an ERID number. The system contained approximately 100,000 ERIDs, amounting to approximately 250,000 documents. Systematic review of the Domino records was performed by going through them sequentially by ERID number and reviewing the image files for those with titles that were either of potential interest or were too ambiguous

to support a judgment. Documents deemed relevant to the LAHDRA project were printed and a DSF was completed.

Records Processing Facility Potential Release Sites Database

The project team also reviewed the RPF's Potential Release Sites (PRS) database, which is far more limited in content compared to the Domino database, using the same approach as for Domino. Other ENV Division records collections that were reviewed include records pertinent to compliance with the National Environmental Policy Act (NEPA), associated environmental impact assessments, Meteorology and Air Quality (MAQ) group records, meteorological data, and Cultural Resources Group reports that include historical information about operations at LANL facilities.

Challenges in Information Gathering at LANL

Access to classified documents at LANL has been more difficult than previously experienced by CDC personnel or LAHDRA team members at any of the other DOE sites that have been subjects of dose reconstruction investigations. The main challenges faced in accessing, reviewing, and arranging relevant documents for public release were associated with the following issues:

- The Cerro Grande fire,
- security stand-downs and the fallout of security incidents involving LANL staff,
- frequent requirements to re-establish need-to-know,
- establishment of security plans for accessing and reviewing documents,
- increased escorting requirements and limitations on numbers of analysts that could work concurrently,
- calls by LANL staff for review of documents by titles alone,
- establishment of seven categories of information to be withheld from the LAHDRA analysts,
- pre-screening by document "owners" and/or classification office contractors to identify deniable-category information,
- difficulties in gaining access to reports issued by entities that no longer exist,

- establishment of an appeal process for use when potentially relevant information was withheld,
- arranging for access to documents at LANL generated by a foreign government,
- a significant backlog of selected documents awaiting classification review and public release,
- limited resources (staffing) at repositories impacting ability of LAHDRA analysts to be present,
- a LANL shutdown in response to a security incident, and
- initiation of pre-screening of documents by LANL Legal staff for privileged information.

Archiving of Relevant Documents Retrieved Under the LAHDRA Project

For each document (or set of documents) deemed to be relevant by the LAHDRA team, a Document Summary Form (DSF) was completed to capture bibliographic data, project-specific information, and analyst comments. A Microsoft® Access database was created to describe and catalogue the information reviewed and collected during this project. A total of 8,372 records were entered into the LAHDRA database. A user-friendly front-end platform was developed for analysts to enter, review, and search the assembled information. As the number of paper copies grew and as scanning technology matured, the LAHDRA team decided that a better way to preserve and present the reference material being collected would be to create scanned images. Therefore, starting in 2003, all documents were scanned, optical character recognition (OCR) processed, and saved as searchable PDF files. Finally, the resulting image file collection was indexed to support searching.

Prioritization of Airborne Radionuclide Releases

During the period of LANL's existence, many operations involving radionuclides have been performed at LANL, resulting in a variety of effluents. As an initial step towards prioritizing historical airborne releases from LANL, the LAHDRA team applied an approach wherein Priority Index (PI) values were calculated by computing the air volume required to dilute the annual activity released to be equal to the maximum effluent concentration (MPC) for each radionuclide set forth by federal regulations. For example: a PI of 10^4 indicates that 10^4 L of air would be required to dilute the released material to a concentration equal to the maximum permissible concentration. The PI is intended to be a guideline to determine if a nuclide set requires further iterations of calculation and refinement, or if it warrants lower priority relative to other nuclides. Priority indices were calculated for plutonium, uranium, tritium,

radioactive lanthanum (RaLa), mixed fission products (MFP), mixed activation products (MAP), and iodine-131.

Prioritization of releases requires estimates of quantities that were released. To date, LANL has not prepared a comprehensive compilation or accounting of its historical airborne radionuclide releases. The most complete compilation of airborne radionuclide effluent data available from LANL was assembled in the 1970s to support the preparation of a Final Environmental Impact Statement (FEIS). This compilation was found to have significant errors and omissions, and the prioritization of LANL releases cannot be considered accurate for the era prior to the 1980s. In addition, with the exception of studies of the impact of the Cerro Grande fire, there has been no study of non-point releases from LANL from incidents such as routine operations or fires from radioactive dumps. For initial prioritization efforts, however, the LAHDRA team used the available release data as reported by LANL, and applied adjustments to account for effects such as loss of material in sample lines. The LAHDRA team performed no independent evaluation or reconstruction of LANL's reported releases. The processes used to prioritize releases of radionuclides from LANL operations are described in Chapter 17.

Data Available to Estimate Plutonium Releases

Airborne plutonium releases were prioritized based on values compiled for the 1979 FEIS, annual environmental surveillance reports, and monthly reports of the CMR-12 and H-1 monitoring sections. All values from 1948 through 1975 were adjusted using a sample line loss correction factor (equal to 5 for 1948-1958 and 2 for 1959-1975) and a filter burial correction factor (equal to 2.33 for 1948-1958 and 1.6 for 1959-1975) based on assessments performed by LANL staff. No effluent data were located for the wartime processing of plutonium in D-Building, and LANL's release estimates include no contribution from D-Building during any period of its operations or from the DP West Site plutonium processing that occurred 1945–1947.

Data Available to Estimate Uranium Releases

Uranium usage and release data were located for 1949–1996. Available documents provided estimates of the quantities of uranium used in explosive testing, as well as some results of stack sampling and analysis. Sample line loss and filter burial correction factors were applied to uranium stack sampling results for periods prior to 1976, as was done for plutonium. While the majority of the uranium expended in a dynamic test is deposited locally, an "aerosolization fraction" was applied to the quantity of uranium expended in a given year in order to calculate the airborne activity potentially carried offsite. Release estimates between 1949 and 1951 reflect only firing site expenditures, while data for 1952 through 1972

includes uranium release estimates based on the 1979 FEIS. After 1973, data from annual environmental surveillance reports were utilized.

Data Available to Estimate Tritium Releases

Airborne tritium release estimates were located for 1967–1996, and no correction factors were applied. Tritium release data were obtained from the data compilations for the 1979 FEIS and the environmental surveillance reports and available stack release data. Tritium was used at LANL as far back as 1944 or 1945; more data are required to determine pre-1967 tritium releases at LANL. LAHDRA staff have found additional documents containing tritium release data associated with episodic releases before and after 1967, and have added them to the project information database, but these data are scattered across many documents, and have not been compiled or used to bound releases prior to 1967.

Data Available to Estimate Radioactive Lanthanum Releases

Prioritization of RaLa releases from 254 explosive tests conducted in Bayo Canyon 1944–1961 was based on a source term evaluation performed by LANL personnel. The aerosolization factor used for uranium was also applied to reported source quantities for the RaLa tests.

Data Available to Estimate Mixed Fission Products Releases

LANL reported a class of airborne effluents as mixed fission products (MFP) from 1961 through 1996, with their main sources being the Omega Site (TA-2) reactors. Radioactivity included in the MFP "nuclide group" for prioritization included releases reported as MFP or as fission product nuclides such as ^{60}Co and ^{137}Cs.

Data Available to Estimate Mixed Activation Products Releases

Another class of airborne effluents called mixed activation products (MAP) was reported by LANL for 1976–1996, with the most significant source being accelerator operations. Radioactivity included in the MAP "nuclide group" for prioritization included releases reported as MAP, Gaseous Mixed Activation Products (G/MAP), Particulate Various Activation Products (P/VAP), and the air activation products ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar.

Data Available to Estimate Iodine-131 Releases

Airborne release estimates for iodine-131 are presented for 1967 through 1986. Release data was obtained from the data compiled for the 1979 FEIS as well as annual environmental surveillance reports.

Results of the Prioritization of Airborne Radionuclide Releases

The LAHDRA prioritization of airborne radionuclide releases shows that, based on LANL compilations, plutonium and uranium were of primary concern until the late 1970s. After that, MAP radionuclides appear to have been of primary concern through 1995. However, in some cases, limited or no data were found in LANL compilations of releases for important nuclides, such as plutonium (D-Building data and pre-1948 data), polonium, tritium before 1967, all nuclides pre-1950, and non-point source emissions.

Table ES-2. Classes of airborne radionuclides with highest Priority Indices for each period of LANL operations

Years	Radionuclide Class with Highest Priority Indices	Range of Annual Priority Indices (L)		
1944-1947	Radioactive Lanthanum	6×10^{13}	to	1×10^{15}
1948-1961	Plutonium	3×10^{15}	to	6×10^{16}
1962-1966	Uranium	2×10^{15}	to	3×10^{15}
1967	Plutonium	4×10^{15}	to	4×10^{15}
1968	Uranium	2×10^{15}	to	2×10^{15}
1969	Mixed Fission Products	4×10^{15}	to	4×10^{15}
1970-1973	Plutonium	1×10^{15}	to	3×10^{15}
1974-1978	Uranium	9×10^{14}	to	1×10^{15}
1979-1995	Mixed Activation Products	3×10^{14}	to	5×10^{15}
1996	Uranium	2×10^{14}	to	2×10^{14}

In 2006, the LAHDRA team conducted a review and calculation was to evaluate reported releases from DP West for 1957 using the actual daily stack reports. This analysis showed that some simple assumptions made in the early 1970s, such as stack or sampler flow rates, were inappropriately used for all periods. The LAHDRA team also found that 40% of all operating hours were not monitored, mostly weekends and holidays. LANL has previously addressed this issue by scaling estimates from operating hours to estimate releases during hours in which no stack measurements were made, an approach that is likely conservative. The LAHDRA team believes that any future efforts to characterize LANL releases should include a more robust method of estimating releases during periods that were not monitored.

There are many possible reasons that plutonium releases were of particular concern for LANL. For example, the crudeness of LANL's early plutonium processing facilities and delayed adoption of single-bank and ultimately multiple-stage HEPA filtration relative to other plants that were more clearly recognized as production facilities were factors in LANL becoming a more significant source of airborne plutonium emissions than it would otherwise have been. The documents discovered by the LAHDRA

team indicate that airborne plutonium releases from LANL before the 1970s were significantly higher than has been officially reported. The relative importance of airborne plutonium releases could increase with further investigation if other identified sources were characterized. The other identified sources include D-Building, DP West Building 12 stacks before 1948, other release points at DP West, early Chemistry and Metallurgical Research (CMR) Building operations beginning in 1953, non-point sources, accidents, and waste disposal operations. These sources were not monitored by LANL or reflected in estimates of plutonium historically released from the site.

Using only LANL summaries of DP West Building 12 stacks alone, and correcting for sample line loss and filter burial (corrections that LANL failed to apply when the data was compiled in the 1970's), the releases greatly exceed the independently established total releases from routine operations for all other DOE plutonium production facilities.

The level of interest in characterizing past releases of plutonium from LANL operations is heightened by the fact that residential areas were built closer to production areas at LANL than at any other major Manhattan Project, U.S Atomic Energy Commission (AEC), or DOE site. The nearest residences, Sundt apartments, were located approximately 200 m from D Building in the Original Technical Area (TA-1), and as little as 50 m from other key buildings in TA-1. From 1948 to 1963, there was also a trailer park on the rim of Los Alamos Canyon just west of DP West site, 1 km west of the DP West Building 12 stacks. This housing area was separated from Material Disposal Area B, a radioactive waste burial ground that experienced a major fire in 1948, by only a fence. The trailer park was also situated directly above Omega Site (TA-2), where five versions of nuclear reactors were operated on the canyon floor because of perceived dangers of associated operations. When a flexible tubing line was run up the wall of Los Alamos Canyon and tied to a tree atop South Mesa to serve as the release point for gases released from the reactors, airborne radioactivity was released at roughly the same elevation as trailer park residents.

Airborne releases of Mixed Activation Products from accelerator operations appear to have been most significant in the majority of years after the 1970s, by which time controls and monitoring of other airborne effluents, such as plutonium, had significantly advanced. Uranium releases yielded relatively high PIs for the late 1960s, 1974-1978, and 1996, but, in general, associated values were lower than those for plutonium.

Airborne tritium releases did not yield the highest PIs for any of the years presented in Table ES-2, but the true importance of the radionuclide cannot yet be definitively evaluated because of the scattered and incomplete nature of effluent measurements or estimates prior to 1967. Incident reports indicate that

sizable episodic releases of tritium occurred between the mid-1940s and 1967, the earliest year for which reports of tritium releases were compiled by LANL.

Conclusions Regarding Airborne Radionuclide Releases

This prioritization effort was intended to present a "first look" at the scope and extent of radionuclides released at LANL over the years of its operation. Because LAHDRA's primary focus was to gather information, it expended limited effort toward entering or evaluating raw data identified in historical LANL documents. In general, the values LAHDRA used for the prioritization came from data previously compiled by LANL, with adjustments made as supported by available data. LAHDRA expended little effort analyzing the data from logbooks or other more detailed data sources. A significant amount of original release information (that is, lab measurements of a filter from a stack) for the 1950s and 1960s is available, though, and could be captured and analyzed if further evaluation of airborne releases is undertaken.

Alternate Methods for Characterizing Airborne Releases

Until around 1978, LANL's airborne plutonium releases were either not measured at all, or were improperly measured or reported. Major release points for which there are no plutonium measurements include the historic D-Building, the first plutonium component manufacturing facility in the world, and DP West Site releases before 1948. D-Building operated until around 1953. Releases from other building stacks at DP Site, aside from the main Building 12 stacks, were also not included in any LANL compilations. The LANL plutonium release compilations also did not consider non-point source emissions, including those from accidents and incidents that released directly to the environment without passing through a stack with an associated monitoring system, such as major fires at plutonium disposal areas in the 1940s, or radioactive disposal area operations that continue to this day. Until around 1959, release points at LANL, such as DP West, were not provided with single stage HEPA filters (Maraman et al. 1975). A second stage of HEPA filters were finally installed around 1973. Until the mid-1950s, the DP West Site stacks were not equipped with an appropriate sampling system. An accurate estimate of LANL plutonium releases thus cannot be made based on LANL data, given LANL's failure to measure all releases. At best, the calculated prioritization represents a lower bound of total LANL releases.

The LAHDRA project examined the feasibility of estimating the releases using two alternate methods: back calculation from soil concentration, and back calculation from plutonium levels in tissue samples collected during autopsies of Los Alamos residents. These alternate methods are described in detail in

Chapter 17. Utilizing these back calculation methods helped the LAHDRA team identify key documents related to LANL releases, and understand the limitations associated with estimating LANL releases through these alternate methods. Future independent assessments of LANL releases will likely incorporate several back calculation methods, comparing the results of each method to available data in order to establish both a lower and upper bound for the releases.

Plutonium Soil Measurements as Indicators of Historical Releases

The historical LANL soil measurement data that are available and that have been used to date in attempting to back calculate the LANL plutonium releases are not ideally suited for this task. The areas around D-Building and DP West have been heavily disturbed, and finding suitable soil sampling locations there would be problematic. However, a LANL technician observed that the hillside of South Mesa across Los Alamos Canyon from the TA-1 has remained relatively undeveloped and undisturbed; as such, this area should be considered for a new soil sampling program. If this work were to be done, the samples should be collected along the canyon rim from the bridge at Diamond Drive to the area across from DP West and analyzed using a new method of measurement called sector field inductively coupled plasma mass spectrometry (SF-ICPMS). This method can distinguish between weapons-grade plutonium (that has not been used in a nuclear weapon) and plutonium attributable to fallout. Using this method for soil analyses could cleanly separate plutonium in the soil from global fallout and soil impacted by LANL releases. This method has been successfully used at the Nevada Test Site (NTS) (Ketterer and Szechenyib 2008).

Without SF-ICPMS, the back calculation must include an estimate of plutonium attributable to global fallout in current samples, and that value must be subtracted from the measured plutonium concentration in the soil sample; this subtraction increases the uncertainty in the calculation. Without any new soil samples, the material found by the LAHDRA team in various LANL document repositories could be used to estimate historical LANL plutonium releases, and could also be used in a rigorous effort to quantify uncertainties associated with the various parameters associated with the back calculation; however, the uncertainties would be greatly reduced if a new program of measurements, including those analyzed via SF-ICPMS, was undertaken.

Analysis of Measurements of Plutonium in Body Tissues of Los Alamos Residents

The LANL Human Tissue Analysis Program was a 35-year effort by LANL to study plutonium levels in workers and in the general United States population. The collection and analysis of tissues was intended to answer questions about the behavior of plutonium in the human body. In later years, the program was expanded to other areas of the country in order to estimate the amount of nuclear fallout people were

subjected to from atmospheric nuclear weapons testing. The non-worker tissue program ended in 1980. Nearly 1,000 decedents had tissues removed during autopsies and sent to LANL by coroners.

The LAHDRA staff attempted an independent analysis of the autopsy program results. This effort, described in Chapter 17, demonstrated that excess plutonium (beyond what would be expected from global fallout from nuclear weapons testing) is present in non-worker residents of Los Alamos. The LAHDRA team also established and a method for developing a residential history for each autopsy case who lived in Los Alamos for any part of his or her life. This information can be used to calculate the distance and bearing from LANL release points, along with the years of occupancy at each residence.

It should be noted that portions of the original tissue samples taken under the LANL human tissue analysis program, as well as logbooks associated with the program, have been maintained by the United States Transuranium and Uranium Registries (USTUR) for many of the autopsy cases. If these samples were to be reanalyzed using ICP-MS, it may be possible to determine how much of any autopsied individual's exposure was due to fallout or releases from LANL. USTUR has performed an initial study of the method with promising results. A re-analysis of the available tissue samples using ICP-MS, combined with the information regarding the distance of each case from known release points over time, might be able to reduce the uncertainty in retrospective dose reconstructions and possibly permit use of the autopsy data for bounding LANL release estimates.

Prioritization of Waterborne Radionuclide Releases

PIs for waterborne radionuclides were calculated for total plutonium ^{89}Sr, ^{90}Sr, and tritium. These radionuclides are the only constituents for which relatively complete historical compilations of liquid releases prepared by LANL were found. It is important to note that LANL also reported waterborne releases for the following radionuclides at various times over the years: ^{227}Ac, ^{241}Am, RaLa, ^{7}Be, ^{134}Cs, ^{137}Cs, ^{57}Co, ^{60}Co, gross alpha, gross beta, ^{54}Mn, ^{22}Na, ^{83}Rb, ^{84}Rb, ^{75}Se, ^{85}Sr, total uranium, ^{234}U, and ^{88}Y. Release data for these nuclides were either only provided for brief time intervals, or were redundant with the longer-term historical compilations. Prioritization of these nuclides was therefore not attempted in this initial assessment.

Estimates of historical releases were obtained from the compilation of data for the 1979 FEIS, from excerpts and compilations of AEC effluent records, and from annual environmental surveillance reports that were issued by LANL beginning in 1971. Priority Indices were calculated by computing the volume of liquid required to dilute the annual activity released to be equal to the maximum effluent concentration per 10 CFR 20. The waterborne radionuclide classes that yielded the highest PIs for each period from 1945 through 1996 are identified in Table ES-3.

Table ES-3. Classes of waterborne radionuclides with highest PIs for periods of LANL operations

Years	Radionuclide Class	Range of Annual Priority Indices (L)		
1945-1955	Plutonium	6.55E+07	to	1.19E+09
1956	^{90}Strontium	3.30E+08	to	3.30E+08
1957-1996	Plutonium	3.50E+07	to	2.94E+09

The current results indicate that in regards to waterborne releases, plutonium is of most concern. It is not yet possible, however, to definitively address the relative importance of waterborne effluents versus airborne effluents. We can note, though, that, in general, pathways for public exposure from liquid releases appear to have not been as complete as those for airborne releases, due to the ephemeral nature of surface water flow in many cases, with a large part of off-site transport possibly occurring during heavy rains or runoff from periods of snow melting.

Prioritization of Chemical Releases

LANL operations have involved many non-radioactive materials, including metals, inorganic chemicals, and organic chemicals, including solvents. To prioritize chemical releases, chemical use and release data were extracted from chemical inventories and various LANL documents. Details regarding these data sources can be found in Chapter 19. Prioritization of chemicals took into account estimates of annual usage and U.S. Environmental Protection Agency (USEPA) toxicity values, such as cancer potency slope factors and reference doses (RfDs). Chemicals that were considered carcinogenic were ranked based on estimated annual usage multiplied by the applicable cancer slope factor. Oral slope factors were used in all but one case because they provided a more conservative (higher) estimate of toxicity for prioritization than the inhalation slope factors. All chemicals with published RfDs were ranked by dividing the annual usage by the applicable RfD. For agents that have both ingestion and inhalation RfDs, the more conservative (lower) value was used. Table ES-4 presents a ranking of each chemical that was documented as used at LANL, for which some usage quantity information was obtained, and for which a cancer potency slope factor and/or reference dose has been published.

The prioritization of chemical releases based on their potential to cause cancer indicated that four of the top five ranked chemicals were organic solvents that were commonly used in chemical processing and for cleaning of metals and other materials. Trichloroethylene ranked highest, indicating highest relative potential for health effects, for both cancer and non-cancer effects. For chemicals with cancer potency slope factors and some usage data available, 2,4,6-trinitrotoluene (TNT) yielded the highest ranking for a

material that was not a solvent, while uranium as a heavy metal toxin ranked highest for non-cancer effects among materials that are not solvents, followed by TNT.

Table ES-4. Ranking of LANL chemicals based on toxicity parameters and indicators of annual usage[a]

Chemical	Slope Factor (SF)	Reference Dose (RfD)	Peak annual use	Ranked based on cancer effects		Ranked based on non-cancer effects	
	$(mg\ kg^{-1}\ d^{-1})^{-1}$	$(mg\ kg^{-1}\ d^{-1})$	(kg)	Use × SF	Rank	Use × RfD^{-1}	Rank
Acetone	-	0.9	18,800	-		20,889	13
Benzene	0.055	0.004	181	10	7	45,250	9
Carbon tetrachloride	0.13	0.0007	558	73	5	797,143	5
Chlorodifluoromethane[b]	-	14.3	32,200	-		2,252	17
Chloroform[c]	0.0805	0.01	3,088	249	4	308,800	7
Dichlorodifluoromethane[b]	-	0.0571	32,200	-		563,923	6
Dioxane	0.011	-	32	0.35	8	-	
Methanol	-	0.5	6,600	-		13,200	14
Methyl ethyl ketone	-	0.6	22,000	-		36,667	12
Methylene chloride	0.008	0.06	2,200	17	6	36,667	11
n-Hexane	-	0.06	304	-		5,067	16
Tetrachloroethylene	0.54	0.01	10,540	5,692	2	1,054,000	4
TNT (2,4,6-trinitrotoluene)	0.03	0.0005	37,950	1,139	3	75,900,909	3
Toluene	-	0.08	3,300	-		41,250	10
Trichloroethane (methyl chloroform)	-	0.2	39,300	-		16,500	8
Trichloroethylene	0.4	0.0003	27,719	11,088	1	92,396,667	1
Uranium (as a heavy metal)	-	0.0006	47,500	-		79,166,667	2
Xylene[b,d]	-	0.0286	290	-		10,140	15

[a] All toxicity parameter values were obtained from Oak Ridge National Laboratory, Risk Assessment Information System.
[b] The inhalation RfD was used because it was more conservative than the oral RfD. In all other cases, oral RfDs were used.
[c] The inhalation SF was used because it was more conservative than the oral RfD. In all other cases, oral SFs were used.
[d] Combined congener values were used (combined, *p-, m-, o-*).

Development of Residential Areas in Los Alamos

Evaluation of off-site exposures from activities at Los Alamos technical areas would require documentation of the development of nearby residential areas over time. While it was initially thought that the 31 houses commandeered from the Los Alamos Ranch School and Anchor Ranch would provide sufficient housing for the projected staff of 30 scientists and their families, it soon became clear that the scope of the challenge to provide housing for Los Alamos residents had been severely underestimated. Pressure to provide housing and the limited availability of suitable land in the region of finger-like mesas and canyons led to the development of housing that, in some cases, was much closer to operational areas than has become customary for government facilities that undertake processing of nuclear materials and high explosives and/or operation of devices, such as reactors or high-energy particle accelerators.

Based on the LAHDRA team's review of historical documents, nine locations were identified as being sites of historical operations that appear to warrant evaluation in terms of potential off-site releases or health effects. The LAHDRA project team collected maps, photographs, and historical documents that describe the history of development of each Los Alamos housing area. The assembled information is summarized in Chapter 15. For each of the nine locations of interest, the following parameters were evaluated to support evaluation of the potential for public health effects:

- The distance from the area to housing areas that were in place during the period(s) that associated operations were active;
- The direction from the location to each housing area; and
- The prevalence of winds from the location toward each the housing area.

Screening-Level Assessment of Airborne Plutonium Releases

Because airborne plutonium releases from DP West Site were documented to have been significantly higher than has been officially reported, and because residential areas were located quite close to the site, two screening-level evaluations using the methodology of the National Council on Radiation Protection and Measurements (NCRP) Report No. 123 (NCRP 1996) were performed. NCRP Report No. 123 provides a series of simple screening techniques that can be utilized to compare estimated dose or risk received from radionuclides released into the environment with a benchmark reference level (NCRP 1996). For atmospheric releases, the report utilizes three conservative models and parameters. Level I screening employs the simplest and most conservative approach, which assumes a concentration based upon the radionuclide concentration at a point source emission (in this case, stack emissions from DP West Site). Level II screening accounts for dispersion into the atmosphere, while Level III includes a

more definitive pathway analysis. It is important to emphasize that the results of the screening calculations are strictly for comparison to an environmental standard (limiting value), to determine if compliance with that standard is assured, or if further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals.

For all screening assessments performed by the LAHDRA team, the limiting value selected was 1.82×10^{-4} Sv y^{-1}, which is based on 1 in 100,000 added risk of fatal or non-fatal cancer using a risk factor of 5.5×10^{-2} Sv^{-1} (ICRP 2007). For each residential location, the pathways considered were inhalation of contaminated air and consumption of contaminated soil and vegetables. Consumption of locally raised meat or milk was not considered. Parameters used by the LAHDRA team are discussed further in Chapter 18.

Evaluations of airborne plutonium releases were performed for two eras to account for the fact residential areas became located closer to DP West over time. The first evaluation was performed for releases during 1949, which is the apparent year of peak emissions for the period prior to 1957. A second screening-level evaluation was performed for releases during 1959, the apparent year of peak emissions after 1957. The year 1957 is significant because it marks the appearance of the Group 18 housing area, resulting in a significant change in the proximity of the nearest residents to DP West.

The results of preliminary screening of airborne ^{239}Pu releases from DP West site Building 12 stacks during 1949 and 1959 are presented in ES-5 and ES-6, respectively. It is important to emphasize that these screening values are based on the incomplete LANL source term; the actual values could be significantly higher if all releases were known and included in these calculations. The screening values for both years exceeded the limiting values in Level I and Level II, prompting application of the screening methodology at the next highest level. The results of the Level III screening indicate that airborne ^{239}Pu releases from Building 12 stacks – as represented by estimated releases during 1949 and 1959 – warrant further evaluation by experts in environmental and radiological assessment.

Table ES-5. Summary of the preliminary screening of airborne ^{239}Pu releases from DP West Site Building 12 stacks during 1949

Level of Screening	Features of Screening Methodology	Screening Value (Sv y^{-1})	Screening Limit exceeded?	NCRP Guidance
I	Vent air, all pathways, concentration at exposure point set equal to 25% of stack concentration.	21.3	Yes	Proceed to Level II
II	Vent air, all pathways, Gaussian plume modeling to exposure point outside near-wake region, wind blows toward exposure point 25% of the time.	0.025	Yes	Proceed to Level III
III	Vent air, specific pathways (inhalation, external exposure, consumption of vegetables), same dispersion assumptions as Level II.	0.025	Yes	"Seek assistance from experts in environmental radiological assessment"

Table ES-6. Summary of the preliminary screening of airborne ^{239}Pu releases from DP West Site Building 12 stacks during 1959 using the methodology of NCRP Report No. 123

Level of Screening	Features of Screening Methodology	Screening Value (Sv y^{-1})	Screening Limit exceeded?	NCRP Guidance
I	Vent air, all pathways, concentration at exposure point set equal to 25% of stack concentration.	13.6	Yes	Proceed to Level II
II	Vent air, all pathways, Gaussian plume modeling to exposure point outside near-wake region, wind blows toward exposure point 25% of the time.	0.061	Yes	Proceed to Level III
III	Vent air, specific pathways (inhalation, external exposure, consumption of vegetables), same dispersion assumptions as Level II.	0.061	Yes	"Seek assistance from experts in environmental radiological assessment"

Screening-Level Assessment of Airborne Tritium Releases

The benefits of incorporating tritium into nuclear weapons design was recognized early in the Manhattan Project. Information regarding tritium uses is summarized in Chapter 7. Project Y personnel requested tritium from Oak Ridge, TN in the spring of 1944. While LANL received tritium in increasing quantities over the decades for use at 10 or more TAs, no airborne tritium effluent data were included in LANL compilations of effluent data for years prior to 1967. Tritium was released to the air at TAs 3, 21, 33, 35, and 41. In addition, tritium was used in firing site (explosive testing) activities, at TA-15 for example. Between 1967 and 1999, annual airborne tritium releases reported by LANL were never lower than 3,000 Ci and peaked at 35,600 Ci in 1977. Scattered incident reports located by LAHDRA analysts describe episodic releases of tritium that total as much as 64,890 Ci in 1965 and 39,000 Ci as early as 1958, each from within the 22-y period of tritium usage for which official reports of LANL releases include no data for the radionuclide.

LANL did not begin monitoring tritium stack releases until 1971. In 1973, the Lab prepared estimates of atmospheric releases for 1967 through 1970 based on accountability data. There are no formal estimates of total tritium releases prior to 1967, though the LAHDRA document collection contains effluent monitoring and other tritium release data for some tritium facilities prior to 1967. Whether the available information represents a complete picture of LANL's total atmospheric tritium releases for the pre-1967 period is currently unknown.

One of the most important factors to consider when evaluating atmospheric releases of tritium for potential health risks is the chemical composition of the release. The difference between tritium gas and tritium oxide is enormous in terms of radiation dose to a human receiver. If inhaled, tritium gas is not incorporated into the body to any appreciable degree, and the only dose consequence is the direct exposure to lung tissue. Tritium oxide, in contrast, behaves like water, and is readily incorporated into body tissues. In terms of radiation dose per unit intake, the dose from tritium oxide exceeds that from tritium gas by four orders of magnitude (ICRP 1996).

Given its application in the weapons program and accelerator operations, tritium at LANL has primarily been used in the form of tritium gas. However, there are some circumstances in which an assumption of the oxide form is appropriate, at least for initial screening purposes. Examples include the use of tritium in explosive testing, and operations involving water reactions with tritium-bearing salts resulting in oxide formation.

As with Plutonium, the NCRP Report No. 123 screening method for radionuclide releases to the environment was used to evaluate atmospheric tritium releases from LANL in terms of their potential risk

to local residents. That assessment is described in Chapter 7. The source term used was the maximum release reported for each of the six TAs that represented the largest contributors to LANL's atmospheric tritium releases. To ensure a meaningful screening result, these release totals were re-stated in terms of the corresponding tritium oxide activity for each total value. The upper bound for the fraction of a tritium gas source that has converted to an oxide form was taken to be 1% based on published studies (see Chapter 7).

Level I screening was performed for the TA-3 release first, since it was the smallest contributor to the tritium oxide source term. The Level I screening evaluation for the TA-3 tritium releases exceeded the screening criterion by a substantial margin. Screening therefore proceeded to Level II and III.

In the Level II screening process, the estimated distances from the release points to the nearest residential locations were used to determine a plume diffusion factor from plots provided in NCRP Report No. 123. The Level II screening evaluations showed that the adjusted screening criterion was exceeded only in the case of TA-35, for which the maximum release was treated as 100% HTO.

The screening-level evaluation suggests that airborne tritium releases from LANL after 1966 were unlikely to have been a source of health risks to local residents around Los Alamos that warrants high priority in any assessment of historical releases from LANL. The possibility cannot be ruled out entirely, however, in light of the screening result for TA-35. The situation could change if releases consisted of a greater fraction of tritium oxide than has been considered here. However, given the degree of conservatism used in applying the NCRP screening method, it appears the impacts of such effects would have to have been substantial before atmospheric tritium releases after 1966 would have posed a significant health risk. Tritium release events before 1967 are described in numerous scattered documents found by the LAHDRA team, but release totals have not been compiled that would support an evaluation of potential off-site exposures. Airborne tritium releases before 1967 represent a notable data gap in what is known about historical releases from LANL operations.

Screening-Level Assessment of Airborne Uranium Releases

Uranium, at various levels of ^{235}U enrichment, has been used in a wide variety of applications at Los Alamos. Information about uranium use is summarized in Chapter 9. Uranium was used as a fissile material in atomic weapons and in "tampers" that confined the explosion, reflected some neutrons that would otherwise escape, and thereby decreased the critical mass of fissile material required to achieve an atomic explosion. Uranium was also used in liquid and solid forms as fuel in various forms of nuclear reactors developed and tested at Los Alamos. Some LANL facilities, including DP East Site, produced fuel for reactors operated elsewhere, such as those in the Rover program. DP West Site's Building 4

housed laboratories for production of enriched uranium hydride, which then was converted to a hot cell facility for examination of irradiated plutonium and enriched uranium fuel elements. Uranium was also used in explosive testing at Los Alamos; LANL staff estimated in 1971 that between 75,000 and 95,000 kg of uranium had been expended in experimental shots at the Lab from 1949 through 1970.

In TA-1, uranium was processed in a "normal" uranium machine shop in C Building's southeast section, in chemistry and metallurgical experiments in D Building, and in the HT (Heat Treatment) Building. Enriched uranium processing, metallurgy, and recovery were conducted in M Building, while normal and enriched uranium were cast and machined in Sigma Building; the eastern portion of the building processed normal uranium, while the western portion processed enriched uranium. TU Building housed machining of normal uranium ("tuballoy"), while TU-1 Building housed recovery of enriched uranium. The original machine shop in V Building machined uranium and beryllium.

The Sigma Complex in TA-3, built in the 1950s and 1960s, has housed extensive laboratory areas for materials synthesis, and processing, characterization, and fabrication of materials such as beryllium, uranium, thallium, and aluminum alloys. These activities have included large-scale metallurgy and fabrication of normal and fully enriched uranium. As of 1969, the CMR Bldg, except for its Wing 9, was used for laboratory work on small quantities of uranium and plutonium. Wing 9 contained hot cells for handling of irradiated uranium and plutonium (see Chapter 8).

To gauge what impact LANL's atmospheric uranium releases may have had in terms of human health risk, the NCRP Report No. 123 screening model (NCRP 1996) was applied to airborne uranium source term information for TA-21. TA-21 was selected because it was the largest source of airborne releases of uranium reported by LANL for its routine (i.e. non-firing site) operations. The screening was performed using the data for 1963, the year of the largest release reported by LANL. Parameters used by the LAHDRA team are discussed further in Chapter 9.

The NCRP Report No. 123 screening evaluation for the 1963 airborne uranium release from TA-21 gave a screening value of 6.9×10^{-4} Sv. This value is larger than the screening criterion, indicating that further investigation of uranium releases from DP Site is warranted.

A screening calculation was also performed for uranium releases from TA-3 using the same method as for the TA-21 release. For TA-3 the maximum reported release occurred in 1956, and the distance to the nearest residential area (the Western Area) was approximately 1,100 m. The resulting screening value was 2.47×10^{-5} Sv. This value is smaller than the screening criterion on its own, however, NCRP 123 recommends dividing the criterion by 10 to account for uncertainties. Doing so gives an adjusted

screening criterion of 1.67×10^{-5} Sv, which is smaller than the calculated screening value. Thus, further investigation of uranium releases from TA-3 is also warranted.

Screening-Level Assessment of Airborne Beryllium Releases

A screening assessment of beryllium concentrations in public areas was performed based on information from historical documents and the atmospheric dispersion screening methods of NCRP Report No. 123. That assessment is described in Chapter 20. Peak releases of airborne beryllium from the "new" SM-39 Shops at TA-3 for years after 1963 were estimated based on documented annual releases for 1964-1966 and 1968-1970, within which the highest value was for 1970. Peak SM-39 Shop releases representative of 1953-1963, before high efficiency particulate air (HEPA) filters of nominal 99.97% efficiency were added, were estimated based on 1970 releases multiplied times a factor of 167. That value is the ratio of the effluent reduction factor for HEPA filters to the reduction factor for the filters (of assumed 95% efficiency) that were in place before HEPA filters were installed. Because of similarity of operations, peak release rates of airborne beryllium from V Shop at TA-1 for 1943 to 1953 were assumed to be equal to those from the SM-39 shop before HEPA filters were added.

Releases from the hot pressing of beryllium oxide (BeO) powder in Q Building at TA-1 were estimated based on a document that indicates that 6,100 lbs of BeO was obtained during 1944 for production of reactor components. Based on an assumed release fraction of 0.25%, it was estimated that 6,900 g of BeO (containing 2,500 g of beryllium) was released over 1,600 working hours in 1944. Releases from the testing of beryllium-containing atomic weapon components fired from a cannon in an annex to B Building at TA-1 were estimated based on a frequency of 1 shot per day, 7 days per week. LAHDRA team members estimated that each 20-mm diameter projectile contained 120 g of beryllium, of which 10% was aerosolized, yielding a release of 12 g per test over a 6-minute period. Peak beryllium releases from explosive testing at the Pulsed High Energy Radiographic Machine Emitting X-rays (PHERMEX) facility at TA-15 were estimated based on a report that beryllium use in explosive tests peaked at 106 kg in 1964. The calculation assumed that 100 shots occurred in 1964, of which 80% did not involve beryllium and 20% did. Of the 20 shots that used beryllium, it was assumed that 16 used 3.31 kg beryllium and four used 13.25 kg. If 10% of the beryllium in one of the larger shots was aerosolized, 1.325 kg would have been released over 15 min.

For the beryllium shops and oxide pressing operations, release or usage estimates were found only in the form of annual totals. In order to estimate how high release rates could have been over shorter periods, detailed monitoring data that are available for airborne plutonium releases from DP West site stacks for 1956 and 1957 were analyzed. The relationships between daily concentrations and weekly, monthly, and

annual average concentrations were characterized, and a table of multipliers was generated that can be applied to annual data to estimate peak releases over a series of shorter durations. To support preliminary screening, airborne beryllium releases were assumed to vary over time like the measured airborne plutonium releases, and annual beryllium releases were converted to release rates over shorter durations so that airborne concentrations could be compared to occupational and ambient exposure limits.

For each beryllium emission source, the distance to the nearest residential area was estimated, and dilution factors were estimated using the method of NCRP Report No. 123's Gaussian plume modeling of releases to the atmosphere. The estimated exposure point concentrations were compared to occupational and ambient concentration limits.

The results of screening of airborne releases from the beryllium operations are presented in Table ES-6. The release rate and concentration values for BeO powder pressing, V Shop, and SM-39 Shop releases are presented as 6-min, 30-min, and 8-h average values that would be expected to be reached or exceeded once per year, and monthly average concentrations that would be expected to be reached or exceeded 5% of the time. For the explosive tests at TA-15, the results in Table ES-7 for periods longer than a week are average values over the periods shown based on 100 shots/year, each with 0.25-h duration that together released 10% of the total beryllium reported expended in 1964. For periods shorter than a month, the results are average values over the periods shown based on one shot, with 0.25-h duration of exposure, occurring during the period and releasing 1.25% of the total beryllium reported expended in 1964.

The screening results indicate that the 8-h time weighted average permissible exposure limit of 2 $\mu g\ m^{-3}$ for beryllium adopted for workers by the AEC and, later, the Occupational Health and Safety Administration (OSHA) could have been exceeded in residential areas by releases from the B-Building gun tests. The OSHA/AEC ceiling limit of 25 $\mu g\ m^{-3}$ for workers could also have been exceeded for releases from those tests based on concentrations estimated for 0.5-h and 0.1-h averaging periods. The USEPA reference concentration of 0.02 $\mu g\ m^{-3}$ could have been exceeded in residential areas by releases from B-Building gun testing, BeO powder pressing, V-Shop machining, and tests at PHERMEX. The National Emission Standard of 0.01 $\mu g\ m^{-3}$ for beryllium in ambient air averaged over a 30-d period could have been exceeded in residential areas from the B-Building gun tests and BeO powder pressing.

The importance of the early beryllium releases is again heightened by the fact that residential areas were unusually close to the original Technical Area, with the nearest residences roughly 50 m from B Building, which was literally across Trinity Drive from numerous Sundt apartments. Sigma, Q, and V Buildings– which all housed beryllium operations– were all within 170 m or less of the nearest residences. While it

is clear that beryllium was viewed as an occupational hazard after 1947, it appears that the potential for public exposure has not been fully evaluated.

Table ES-7. Results of a preliminary screening assessment of airborne beryllium concentrations in residential areas from identified emission sources at LANL

	B-Building Gun Tests[a]	BeO Powder Pressing	V Shop 1943-48	V Shop 1949-53	SM-39 Shop 1953 to 1963	SM-39 Shop after 1963	PHERMEX Tests[a]
Distance to exposure point (m)	49	140	170	170	960	960	4500
Relative concentration (s m^{-3})	1.1×10^{-2}	2.5×10^{-4}	1.1×10^{-4}	1.1×10^{-4}	6.9×10^{-6}	6.9×10^{-6}	2.5×10^{-6}
Release rates (µg s^{-1}) for relevant averaging periods;							
0.1 h:	33,000	64,000	12,000	610	610	3.7	1,500,000
0.5 h:	6,700	20,000	3,900	190	190	1.2	740,000
8 h:	420	3,600	680	34	34	0.20	46,000
730 h (1 month):	140	150	29	1.4	1.4	0.0086	670
Exposure point concentrations (µg m^{-3}) for relevant averaging periods;							
0.1 h:	**350**[c]	16	1.4	0.069	0.0042	0.000025	**3.7**[d]
0.5 h:	**71**[c]	5.1	0.44	0.022	0.0013	0.0000080	1.8
8 h:	**4.4**[b]	**0.90**[d]	**0.077**[d]	0.0038	0.00023	0.0000014	**0.12**[d]
730 h (1 month):	**1.5**[e]	**0.038**[e]	0.0033	0.00016	0.000010	0.000000059	0.0017

[a] Episodic releases

[b] Possible exceedance of OSHA/AEC 8-h time weighted average limit = 2 µg m^{-3}

[c] Possible exceedance of OSHA/AEC ceiling limit = 25 µg m^{-3}

[d] Possible exceedance of USEPA Reference Concentration = 0.02 µg m^{-3}

[e]Possible exceedance of National Emission Standard for ambient air averaged over a 30-d period = 0.01 µg m^{-3}

Potential Doses to Members of the Public from the Trinity Test

During World War II, two atomic weapon concepts were carried through to production at LANL. The implosion-assembled, plutonium-based design was by far the more complicated of the two. Testing that device was considered necessary both because of the "enormous step" of moving from theory and experiments with a combat weapon to its actual production, and also because of the realization that, if the device failed over enemy territory, "the surprise factor would be lost and the enemy would be presented with a large amount of active material in recoverable form" (LANL, undated) The "Fat Man" device was successfully tested at the Trinity Site near Socorro, New Mexico on July 16, 1945, and another was dropped over Japan 24 days later. Viewed by some as one of the most significant events in world history, the Trinity test fell within the scope of the LAHDRA investigation. Information about the Trinity test that was gathered by the LAHDRA team is summarized in Chapter 10 of this report.

To preserve the secrecy of the atomic bomb mission, New Mexico residents were neither warned before the July 16, 1945 Trinity blast, informed of residual health hazards afterward, or evacuated before, during, or after the test. Exposure rates on the day of the world's first nuclear explosion measured up to 15 or 20 R h^{-1} in public areas northeast of ground zero at distances around 20 miles, near Hoot Owl Canyon. These critical measurements were made using instruments that were crude, ill suited to field use, and incapable of effectively measuring alpha contamination from about 4.8 kg of the unfissioned plutonium that was dispersed. Vehicle shielding and contamination were recognized, but not corrected for. The terrain and air flow patterns caused the highest levels of fallout to occur in areas in and around what became known to Manhattan Engineer District (MED) and Army personnel as "Hot Canyon." The residential areas where highest exposure rates were measured on the day following the test were unknown to monitoring teams, and were not even visited on July 16, 1945, so exposure rates there on test day could have been even higher. Ranchers reported that fallout "snowed down" on local surfaces for days after the blast (Thompson 1995). A rancher whose house was 20 mi northeast of Trinity reported that "for four or five days after [the blast], a white substance like flour settled on everything" (Thompson 1995). Because local ground water was not palatable to humans, many local residents collected rain water off their metal roofs into cisterns for drinking water. Documents indicate that it rained the night after the test, so fresh fallout was likely consumed in collected water. Livestock were raised in the area, with most ranches having one or more dairy cows, and a ranch near Hot Canyon maintaining a herd of 200 goats.

Fallout from the world's first nuclear test was measured in cardboard used by Kodak after it observed spotting on its film. The contamination was traced back to cardboard that had been contaminated by an Indiana paper mill's use of river water contaminated by the Trinity fallout. Airplanes equipped with

filters followed the Trinity cloud across Kansas, Iowa, Indiana, upstate New York, New England, and out to sea. If modern monitoring methods had been available at the time, the contamination would likely have been detected worldwide.

All evaluations of public exposures from the Trinity blast published to date have been incomplete in that they have not reflected the internal doses received by residents from intakes of airborne radioactivity and contaminated water and food. Some unique characteristics of the Trinity event amplified the significance of those omissions. Because the Fat Man device was detonated so close to the ground, members of the public lived less than 20 miles downwind and were not relocated, terrain features and wind patterns caused "hot spots" of radioactive fallout, and lifestyles of local ranchers led to intakes of radioactivity via consumption of water, milk, and homegrown vegetables; it appears that internal radiation doses could have posed significant health risks for individuals exposed after the blast.

The young health physics community had never faced the challenge of monitoring such an extensive environmental release of fission products, activation products, and unfissioned plutonium, and wartime pressures to maintain secrecy and minimize legal claims led to decisions that would not likely have been made in later tests. Different standards of safety were applied to informed project workers than to uninformed members of the public. Project workers knew enough to evacuate areas when high exposure rates were measured, or to take the necessary precautions to minimize exposure, but members of the public did not realize that changes in their behavior were prudent, and project staff did not call for evacuations or protective measures even though predetermined tolerances for exposure rate and projected total exposure had been exceeded.

Too much remains undetermined about exposures from the Trinity test to put the event in perspective as a source of public radiation exposure or to defensibly address the extent to which people were harmed. Beyond omission of internal doses, all assessments released to date are based on monitoring data that have not been subjected to the processes used in modern dose reconstruction studies that include quality checking, cross-checking against other data sources, application of appropriate adjustments or corrections, and uncertainty analysis.

Findings of the LAHDRA Project

The LAHDRA project has significantly expanded the quantity of original documentation that is publicly available relevant to past operations at LANL, activities by LANL personnel within New Mexico, and the potential for public health effects from past environmental releases.

The gathered set of information is neither perfect nor complete. Some documents that were generated will never be found because of their loss or destruction, others are difficult to read because of their age and repeated photocopying, and most of the authors and participants from the periods of highest releases have passed away. However, in spite of these factors the members of the LAHDRA study team believe that enough information exists to reconstruct public exposures from the most significant of LANL's releases to a degree of certainty sufficient to allow health professionals to judge if significant elevations of health effects should be expected or measurable. For the latter part of the project, some documents containing certain categories of sensitive information were withheld from review by LAHDRA analysts. Because documents in these categories included nuclear weapon design details, foreign intelligence, and other types of information truly not relevant to studies of off-site releases or health effects, it does not appear that any information needed for dose reconstruction was withheld. And while text was redacted from many selected documents prior to public release, LAHDRA analysts had access to original and redacted copies, and could verify that redacted text did not contain information that would be needed for dose reconstruction.

The information gathered by the LAHDRA team indicates that airborne releases to the environment from LANL operations were significantly greater than has been officially reported or published to the scientific community. The preliminary prioritization steps that have been performed within the LAHDRA project, while quite simple, have provided information regarding the relative importance of past releases of airborne radionuclides, waterborne radionuclides, and chemicals. In general, the LAHDRA team has shown that early releases (1940s-1960s) were more important than those that followed, and that plutonium was the most important radionuclide released in those early years. Airborne activation products from accelerator operations were most important after the late-1970s, and plutonium was important for waterborne releases from the mid-1940s onward. Among chemicals released, organic solvents as a class were likely the most important, followed by TNT and uranium as a heavy metal.

While prioritization analyses have provided relative rankings of contaminants within categories, the preliminary analyses described herein provided no estimates of concentrations to which members of the public were exposed, resulting intakes, or doses to members of the public that could be converted to estimated health risks or compared to toxicological benchmarks or decision criteria. Priority Indices based on dilution volumes required to be in compliance with maximum allowable effluent concentrations do not reflect how uptake factors vary between radionuclides, or the decay that occurs between release point and the location of potential public exposure. And because of the paucity of details regarding uses and releases of chemicals before the 1970s, the preliminary ranking process used for toxic chemicals did

not incorporate estimates of the fractions of quantities of chemicals that were on-hand or used that may have been released to the environment.

LAHDRA has been almost exclusively an information gathering effort. If estimates of historical exposures to members of the public are desired for the releases that have been identified and prioritized by the LAHDRA team, it will be necessary to delineate pathways of human exposure that were complete, to characterize environmental fate and transport, and to calculate doses and the subsequent health risks to groups who were exposed. Methods for performing these steps have been developed and applied to numerous other atomic weapons complex sites, but they would need additional dimensions to properly reflect the effects of the complex terrain in which LANL is set, and to represent the transport of waterborne releases that often soak into dry stream beds before they travel very far, transported, in a large part, by occasional high flow events washing them toward the Rio Grande.

A number of historical operations have been identified by LAHDRA analysts as areas that might be particularly important in terms of off-site exposures. In addition, critical information gaps have been identified in several areas.

- **Early airborne releases of plutonium.** Plutonium was processed in crude facilities in D Building during World War II, and many roof-top vents were unfiltered and unmonitored. After DP West Site took over production late in 1945, there was some filtering of releases, but poor monitoring practices caused releases to be underestimated. DP West releases for 1948-1955 alone were over 10-times the total reported by the Lab for operations before 1973. Screening-level assessments of public exposures from plutonium releases in 1949 and 1959 indicate that airborne plutonium releases warrant further evaluation.

- **Airborne beryllium releases.** Los Alamos used significant quantities of beryllium before the health hazards of the material were fully appreciated, and it was processed very close to residential areas. Preliminary screening indicated that early beryllium processing could have resulted in concentrations in residential areas that exceeded worker exposure limits, the USEPA reference concentration, and the National Emission Standard for beryllium.

- **Public exposures from the Trinity test.** New Mexico residents were neither warned before the 1945 Trinity blast, informed of health hazards afterward, nor evacuated before, during, or after the test. Exposure rates in public areas from the world's first nuclear explosion were measured at levels 10,000-times higher than currently allowed. Residents reported that fallout "snowed down" for days after the blast, most had dairy cows, and most collected rain water off their roofs for

drinking. All assessments of doses from the Trinity test issued to date have been incomplete in that they have not addressed internal doses received after intakes of radioactivity through inhalation or consumption of contaminated water or food products.

- **Airborne uranium releases.** LANL has used uranium since its beginnings in enrichments ranging from depleted to highly enriched. It has been machined and fabricated into weapon and reactor components, and large quantities have been expended in explosive testing. Operational airborne uranium releases warrant further investigation, based on the preliminary screening calculations we performed for TA-3 and TA-21.

- **Tritium releases before 1967.** LANL used tritium as early as 1944, and received it in increasing quantities in the decades that followed for use at ten or more areas of the Lab. In spite of this, LANL compilations of effluent data include no tritium releases before 1967. LAHDRA team members located scattered documents that describe numerous episodic releases within the 22-year period of tritium usage for which official reports of LANL releases include no data for the radionuclide. These documents call into question the release estimates reported by LANL for 1967 forward, and indicate that releases before 1967 constitute a data gap that must be addressed if the health significance of LANL tritium releases is to be evaluated.

Based upon the findings of the LAHDRA project, CDC and other interested parties will judge if the available information indicates that past releases of any materials are sufficiently high enough to warrant detailed investigation of past releases and public exposures, and if it appears that sufficient information exists to support more detailed investigation if the requisite funding were to be made available.

Potential further investigations that could be undertaken for one or more contaminants of highest priority could range from screening level assessments of potential public exposures to more rigorous exposure assessments such as those conducted for other MED/AEC/DOE sites, which have become known as dose reconstructions. Unlike the prioritization analyses performed to date, these assessments, if they are undertaken, would likely incorporate environmental transport modeling, exposure pathway analysis, and reflection of the uncertainties and variability associated with input data, assumptions, and models, so that the ranges of exposures received by likely members of the public can be specified at a stated level of confidence. Assessments of that type are often performed in an iterative fashion, with uncertainty analyses focusing research on assessment components that are contributing most to the overall uncertainty of results. Further refinement can be directed to those elements, and the process can be repeated until the uncertainty of results is acceptable, or cannot be further reduced.

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Chapter 1: Introduction to the LAHDRA Project

The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project began in early 1999. It is being conducted by the Centers for Disease Control and Prevention (CDC), National Center for Environmental Health. Much of the work of the project was conducted by contractors to CDC, namely ChemRisk L.L.C., Shonka Research Associates Inc., ENSR Corporation, and Advanced Technologies and Laboratories International, Inc.

The primary purpose of the LAHDRA project is to identify the information that is available concerning past releases of radionuclides and chemicals from the government complex at Los Alamos, New Mexico. Located in northern New Mexico and owned by the Department of Energy, the Los Alamos facilities have been managed by the University of California since 1943, when "Project Y" was born as part of the Manhattan Project to create the first atomic weapons. Project Y became known as Los Alamos Laboratory, and its name changed to Los Alamos Scientific Laboratory in 1947, and then to Los Alamos National Laboratory in 1981. For sake of simplicity, in this document we will refer to this facility as "LANL" from its initial founding to present day. LANL's responsibilities have expanded since the wartime years to include thermonuclear weapon design, high explosives and ordnance development and testing, weapons safety, nuclear reactor research, waste disposal or incineration, chemistry, criticality experimentation, tritium handling, biophysics, and radiobiology.

LANL operations have not proceeded without health hazards or environmental impacts. Approximately 30 people have been killed in incidents ranging from criticality experiments to accidents with high explosives. Significant quantities of plutonium, uranium, and a wide variety of other toxic substances have been processed and released to the environment in quantities that, in some cases, are not well known. The project team is investigating the materials used throughout LANL's history of operations to identify and prioritize releases in terms of their apparent relative importance from the standpoint of potential off-site health effects. Based on the project's findings, CDC will work with stakeholders to determine if more-detailed assessments of past releases are warranted. Should additional investigations be warranted, they might take the form of screening-level evaluations, or they could progress to detailed dose reconstructions for those releases of highest priority.

In more specific terms, CDC's model of dose reconstruction involves a process that can be divided into as many as five phases:

- Retrieval and Assessment of Data

- Initial Source Term Development and Pathway Analysis
- Screening Dose and Exposure Calculations
- Development of Methods for Assessing Environmental Doses
- Calculation of Environmental Exposures, Doses, and Risks

CDC has completed various stages of this process at INEEL, Savannah River, and LANL. Various stages of the process may overlap at times, and stages may be performed iteratively. All stages may not be necessary at all sites. Each stage involves CDC staff, contractors, and the public. The CDC project at Los Alamos is in the initial, information-gathering phase.

The Products of the LAHDRA Project

The products of the LAHDRA project include:

- this report;
- a database that contains bibliographic information and summaries of the content of relevant documents that were located by the project team;
- sets of copies of the most relevant documents, to be made available by DOE in a reading room in Albuquerque;
- a collection of electronic document images, saved as Portable Document Format (PDF) files, of all documents for which paper copies or electronic files were obtained;
- a chronology of incidents and off-normal events identified in review of reports prepared by Los Alamos' Health Division.

The Project Information Database

A Microsoft® Access database was created to store the information reviewed and collected during this project. The CDC defined the basic database structure and values of many of the fields at the onset of the project. Throughout the project, a few additional fields were added to the database based on analyst and staff comments; these changes were mostly for administrative use. A user-friendly front-end was developed for use by the project analysts for reviewing the information collected. The database includes a form created for entering the information from the DSFs completed by document analysts in the field, and also a form to perform searches on all the information that has been entered. In the search form, users can search every field on the DSF. Users can choose to see the results of the search either in a report format or in HTML format. HTML format provides users with hyperlinks to open the documents associated with the DSF in a scanned searchable image format called portable document format (PDF).

As each DSF was entered into the project database, it was assigned a unique sequential Repository Number. This designation was used to track the information throughout the remainder of the project. Many of the reference citations in this report include repository numbers, often abbreviated as "Repos. No." Note that a repository number may represent a number of related, individual documents.

Figure 1-1: One of several sets of copies of documents selected by the LAHDRA team

The project database has been made available to the public by placing it in the Zimmerman Library at the University of New Mexico in Albuquerque. Users may search the bibliographic information captured on the document summary forms and perform full-text searches of the documents that have been scanned to PDF.

Copies of Documents Obtained by the Project Team

The project repository contains paper copies of documents selected as relevant by the project team and released by LANL. This repository currently contains over 275000 pages of documents. These documents are arranged sequentially by Repository Number. A duplicate set of the project's document repository is maintained at the Zimmerman Library at the University of New Mexico in Albuquerque. This location was selected by the U.S. Department of Energy as the official Public Reading Room for this Project.

Figure 1-2: Dan Barkley of UNM discusses project records at Zimmerman Library in Albuquerque with CDC project staff

The Zimmerman Library is located on the University of New Mexico's (UNM's) main campus. The library's Government Information Department is a regional depository for government documents. Documents can be requested at the information desk, and photocopies can be made at a nominal cost using copy machines in the immediate area.

Directions to the Public Reading Room at the University of New Mexico:

Head east from the Central Avenue exit from I-25. Continuing east on Central Avenue, pass through the signal at University Avenue. UNM will be on the left. The third light after University Avenue will be Stanford Drive. Take a left on Stanford Drive to enter the UNM campus. Take another left at the "T." On the right will be Visitor Parking. After parking, head north and slightly west across campus. Zimmerman Library is just northwest of the Student Union Building. The Government Information Department is located in the basement of the library.

Contact: Dan Barkley, phone: (505) 277-7180, fax: (505) 277-6019; barkley@unm.edu

Document Images

As the number of paper copies grew and scanning technology matured, it was decided that a better way to preserve and present the reference material being collected by the LAHDRA team would be as scanned images. Ultimately, all of the information was scanned in as PDF files and an Adobe Acrobat full text search capability was developed.

Figure 1-3 depicts the progression of a document from preparation of a handwritten DSF through input into the Access database with a link to the document image file.

The documents have been scanned using a high-speed, high-capacity scanner running at 50 pages per minute in simplex mode or 45 pages per minute in duplex mode. Images may be scanned to a maximum resolution of 600 dpi; however, a resolution of 200 dpi is typically used. This resolution provides a compromise between image quality and file size.

The scanning software used includes a proprietary “VirtualReScan” (VRS) feature that allows mixed batches of documents to be scanned without adjustments. VRS technology automatically detects, de-skews, crops, and brightens images as needed, regardless of document shape, size and color.

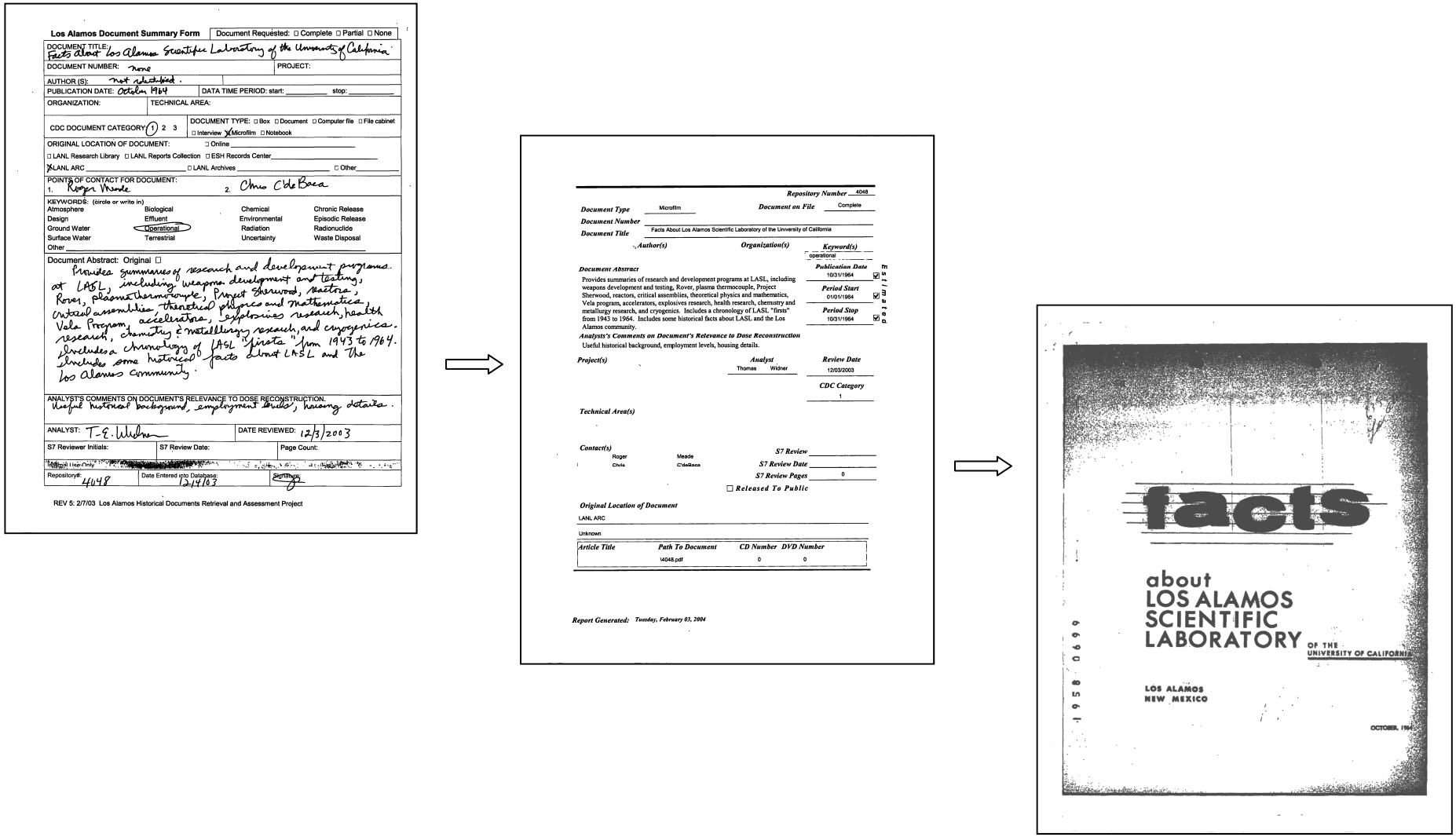

Figure 1-3: Original DSF, Access database DSF, and original document PDF

After the documents are scanned to optimized, interim image files, Adobe® Acrobat® Capture® is used to convert the images to searchable PDF files.

Once documents are scanned to searchable PDF files, they are indexed using Adobe® Acrobat® Professional's Catalog tool. The Catalog tool generates an index definition file, providing efficient full-text searching across all of the PDF files in the index.

Currently all documents in the project repository have been scanned to PDF files. The full-text search capability across all of the documents retrieved to date provides a powerful augmentation to the bibliographic search capabilities of the Access database. However, due to the poor quality of some of the documents retrieved, the OCR process can miss individual words or passages of text. It is therefore important that both the bibliographic and full-text search capabilities be used to find information of interest. Some manual verification and correction of the OCR process has been performed, but this effort is limited by budget constraints.

Chronology of Incidents and Off-Normal Events

Progress reports issues by the Los Alamos Health Division (H Division) are particularly useful sources of information about operations, releases, episodic events, and accidents involving radionuclides and other toxic materials. The LAHDRA team has made a concerted effort to obtain as many H-Division progress reports as possible. The project information database currently contains summary data for hundreds of Health Group and H-Division progress reports. At present, these reports cover a date range from 1943 to 1990. Most of the reports cover a one month period, though there are also annual reports and, in later years, quarterly reports. The monthly reports were discontinued around early 1965 in favor of quarterly reports.

A chronology of episodic or off-normal events described in these reports will be a valuable resource for depicting historical release pathways, particularly for describing mechanisms for fugitive emissions and other unmonitored pathways that might otherwise go unaccounted. And for hazardous chemicals, the anecdotal information contained in many H-Division reports makes up a large part of what we know about historical usage and actual or potential releases.

The LAHDRA project team began its review of H-Division reports in 2004, but could not complete the review before project work was suspended. Now that work has resumed, this effort has continued as an element of the prioritization process as document search and retrieval progresses. The latest available version of a chronology of episodic or off-normal events, based on reports that have been reviewed as of

the date of release of this report, is presented in Appendix L. Each event is described briefly, and Repository Number and page number references are provided.

The H-Division progress reports were compiled by the Division Leader, and contained information submitted by the leaders of the individual groups that made up the Health Division at a given time. While the material they provide is largely of a summary nature, the reports are nonetheless detailed, and provide an array of information. Collectively, the reports provide a chronology of laboratory operations, with an emphasis on experience with hazardous materials. They cover the breadth of the subjects now known as health physics and industrial hygiene, and provide information in a number of areas of interest to the LAHDRA Project, including:

- materials (contaminants) of concern (radionuclides, chemicals, and explosives),
- instrumentation issues,
- monitoring/sampling of waste streams/effluents,
- monitoring of special (short-duration) programs and experiments,
- unmonitored releases and fugitive emissions,
- environmental monitoring,
- episodic events and incidents involving spread of materials to private property or members of the public,
- facility operations (including ventilation system issues, modifications, etc.),
- waste disposal practices and issues.

Of particular note is the fact the reports provide information on various chemicals and compounds that were being utilized at various times, where the materials were being used, and for what purpose they were being used. While this information is largely qualitative, it still provides a valuable resource for prioritizing non-radioactive hazardous materials for time periods for which such information is scarce. The reports also yield valuable information regarding sources of unmonitored releases and fugitive emissions that are always difficult to evaluate in retrospective assessments.

Beyond the specific information contained in the individual H-division progress reports, the continuity of the information they provide collectively (the monthly reports in particular) gives insight into chronic and recurring concerns that may not have been apparent at the time. Applied retrospectively, this information can be used to advance both the document search tasks and the evaluation of information obtained relative to off-site releases and potential effects.

Contents of this Report

This Interim Report represents a summary of information that has been obtained by the LAHDRA project team regarding:

- historical operations at LANL,
- the materials that were used,
- the materials that were likely released off site,
- development of residential areas around LANL, and
- the relative importance of identified releases in terms of potential health risks.

The information in this report was obtained from records reviewed at LANL by the project team, some books and reports that are publicly available, and some interviews with past and current LANL workers.

Preparation of LAHDRA project reports has been an iterative process. A preliminary draft report was issued in February, 2002, so that interested parties could see the types of information the LAHDRA team was finding, be introduced to the approaches being taken to interpret the information that was found, and offer comments and criticism as to how the report could be improved as work progressed. A Draft Interim Report and then an Interim Report were issued in 2004, as the first LAHDRA contract came to a close, and an additional iteration of the project report was issued in January, 2006.

Figure1-4: An early photo of the main gate into LANL

While millions of documents have been reviewed at LANL, the information gathering is not complete. For various reasons that will be discussed later in this report, document review has taken significantly longer than expected. There are now known to be significantly more documents at LANL than were originally estimated, and the processes for access to classified documents and for public release of relevant documents have been more complicated and time consuming than was expected.

Based on the findings of the ongoing information gathering process, which are summarized in this report and evidenced in the project information database, the CDC will work with stake holders to evaluate

whether historical releases for radionuclides or other toxic materials from LANL operations warrant more detailed evaluation.

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Chapter 2: Overview of Historical Operations at LANL

When the Los Alamos facility was created, it had a single mission— to perfect the design and manufacture of the first atomic bombs. The initial plan for the first atomic weapon was for a "gun assembled" device that would use slow-burning propellants, as shown in Fig. 2-1 (LANL, 1983). Gun-assembled weapons may be designed on the principle of using a propellant to drive a mass of fissile material at a target of the same material to attain a supercritical assembly. To develop and build gun-assembled weapons, LANL personnel initially experimented with using enriched uranium (^{235}U) and plutonium as the fissionable material. Other necessary materials included an explosive propellant, a detonator to set off that propellant, and precision machined housings to support assembly of the critical mass in the necessary configuration within the required time frame. Part of the housings were cases of heavy metal (such as uranium), called "tampers," that confined the explosion, reflected some neutrons that would otherwise escape, and thereby decreased the "critical mass" of fissile material required to give rise to an atomic explosion (Serber et al., 1992).

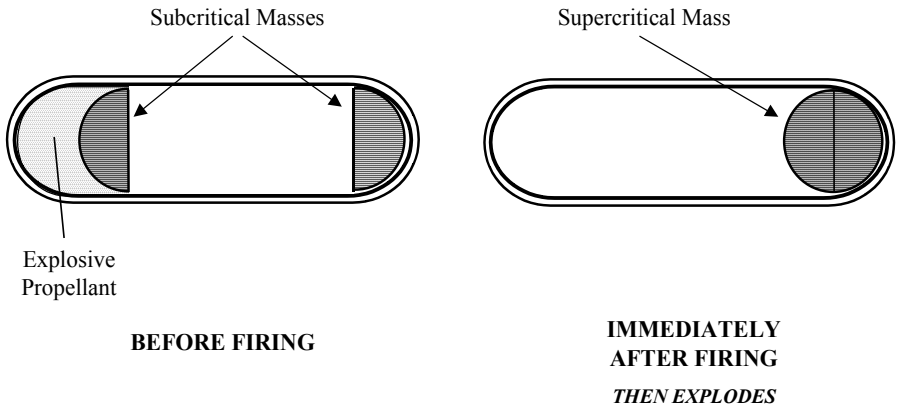


Fig. 2-1. Concepts of a gun-assembled atomic weapon

Early development work centered on potential use of ^{235}U and ^{239}Pu in gun-assembled devices. Top priority was given to developing a plutonium-projectile gun device, which posed more problems than the uranium design because of tighter purity specifications and the need for a faster assembly velocity. In July, 1944, researchers discovered that the plutonium being used at LANL would not work in gun-assembled weapons because of the presence of more of the ^{240}Pu isotope than expected amidst the desired ^{239}Pu. The spontaneous neutron emission rate from that plutonium was several hundred times greater than allowable. As a result, while research on the "certain to work" uranium gun device continued, development of a plutonium device shifted to an implosion-assembled design. A second design was needed because the delivery rate for enriched uranium would only support production of a single uranium

weapon within the imposed schedule, and scientists thought that more than one weapon would be necessary. Implosion-assembled weapons may be designed on the principle of squeezing (compressing) the fissile material to super-criticality by detonating a high-explosive implosion system. The implosion type bomb is depicted in Fig. 2-2 (LANL, 1983).

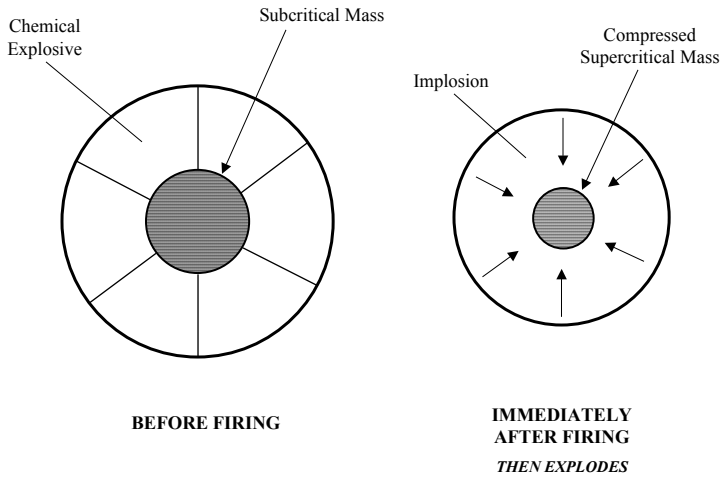


Fig. 2-2. Concepts of the implosion-assembled atomic weapon

To develop and build implosion-assembled devices, much experimentation had to be done with chemical high explosives to try to precisely assemble something with great symmetry, in contrast to their typical explosive uses. Work on high explosives centered on achieving precise timing of detonations at the surface of the explosive and using "lenses" of a different explosive to focus the resulting shock waves on the metal sphere in the center of the device (Serber et al., 1992). In addition to fissionable material, high explosives, detonators, and tamper material, work on implosion-assembled devices included developing "initiators" that acted as strong sources of neutrons at the precise time that the supercritical masses came into position, to make sure that the fission chain reaction started when it had to. These initiators used materials including radium, beryllium, and polonium (Serber et al., 1992).

With the successful demonstration of fission devices, scientists were able to achieve the high temperatures necessary to bring about fusion of hydrogen nuclei for use in the "Super" bomb that had been studied for years as a theoretical possibility. Viewed by some as LANL's second historic mission, development of thermonuclear or "hydrogen" devices led to the first full-scale testing in the Mike shot in the Pacific in late 1952. Thermonuclear devices rely on a two-staged process, in which energy from a fission "primary" is contained and used to trigger a fusion or fusion-fission reaction in a physically-separate "secondary" portion of the device. These concepts of a staged thermonuclear weapon are shown in Fig. 2-3 (LANL, 1983).

Many of the materials needed for thermonuclear devices were the same as those needed for a gun-assembled or implosion-assembled device, plus fuel for the fusion reaction. The first thermonuclear devices used a liquid fuel, such as deuterium, that required significant developments in cryogenics in order to keep it below its boiling point of -250 Celsius. Later devices used lithium deuteride fuel, in solid form, which "breeds" tritium when exposed to neutrons.

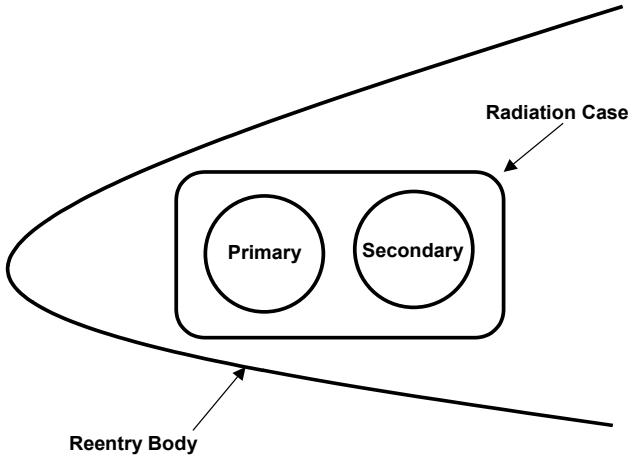


Fig. 2-3. Concepts of a staged nuclear weapon

After World War II, LANL scientists and engineers were involved with developing and testing numerous nuclear design devices that were more and more powerful, compact, reliable, dependably deployable in the field, and able to be contained in a variety of delivery vehicles suited to various combat objectives. LANL scientists were involved with many nuclear device tests within the continental United States, the Pacific, and in Alaska, including some that were part of the Plowshare program, which aimed to develop peaceful applications for nuclear explosives.

Los Alamos was the lead site for U.S. nuclear component fabrication until 1949, when the Hanford Plutonium Finishing Plant in Washington began making "pits," the central cores of the primary stages of nuclear devices (USDOE, 1997). In 1952, the Rocky Flats Plant near Denver began making pit components. After 1949, LANL became a backup production facility; and designed, developed, and fabricated nuclear components for test devices. Pit production stopped at the Hanford facility in 1965, and the Rocky Flats Plant ceased operations in 1989. From time to time, LANL was called upon to perform special functions in its backup role. Because of an accident at the Hanford Plutonium Finishing Plant in 1984, for example, plutonium was sent in oxide form to LANL to be converted to metal (USDOE, 1997). Special activity at LANL might also have occurred after major fires in plutonium facilities at Rocky Flats in 1957 and 1969.

Operations, facilities, and capabilities that were needed to support developing and producing various types of nuclear devices expanded in many cases to support other missions after World War II. Programs in chemistry, metallurgy, and low temperature physics expanded into non-military development and fundamental research; LANL developed, for example, one of the largest experimental machine shops in the country. Its Health Division grew significantly and expanded into many areas of health physics, industrial hygiene, medicine, safety, and biomedical research regarding people and radiation.

Early reactors that were built to confirm critical masses for fissionable materials and to study properties of fission and the behavior of resulting neutrons were the forerunners of a variety of reactors that were designed, and, in some cases, built and operated at LANL. While some of these reactors served as sources of neutrons for various types of nuclear research or for materials testing, other designs were pursued for potential applications in power generation and propulsion of nuclear rockets into deep space. Some of the first significant steps towards controlled nuclear fusion as a power source were taken at LANL, and its plasma thermocouple program explored methods for directly converting fission energy to electricity for potential applications in spacecraft propulsion.

Operations at LANL occur in land divisions called Technical Areas, or TAs. Table 2-1 contains a listing of these TAs, including some that have been abandoned, some that were combined with other TAs, and some that were cancelled before they ever became operational. Table 2-1 also contains listings of some of the various radioactive materials that are documented to have been used at each technical area, based on information reviewed to date.

Figures 2-4 and 2-5 show the location of LANL within New Mexico and the layout of the modern-day TAs, while Fig. 2-6 presents a timeline of some selected operations and activities at (or related to) LANL.

Table 2-1. LANL Technical Areas (TAs) past and present

TA	Name and Description	Materials Involved[a]
TA-0	Los Alamos Townsite: leased space in Los Alamos and White Rock for training, support, unclassified research and development, community outreach, museum	None
TA-1	Original Main Technical Area (inactive): 1943-65 active; turned over to Los Alamos County or private interest in 1966; all contamination removed by 1975	EU, DU, ^{238,239}Pu, ^{241}Am, ^{210}Po, ^{140}Ba, ^{140}La
TA-2	a.k.a.[c] Omega Site: Early critical assembly experiments. Water Boilers (1944-1974); Pu Fast Reactor, a.k.a. Clementine (1946–1950); and Omega West Reactor (1956-1992); reactors used for critical experiments up until 1946 when experiments were moved to TA-18. Omega Site reactors operations were then centered around neutron experiments and isotope production	^{239}Pu; ^{131}I; ^{88}Rb; ^{137}Cs; ^{131}Xe; ^{125}I; ^{41}Ar, ^{3}H
TA-3	Core Area (a.k.a. South Mesa Site; active 1949 to present): detonator manufacturing, metallurgy burn pit, firing sites from 1943-49. Listed below are brief descriptions of key TA-3 operations.	^{238,239}Pu, ^{235,238}U, DU, NU, ^{210}Po
TA-3-29	Chemistry and Metallurgy Research: actinide chemistry and metallurgy research since 1952 to present	^{239}Pu; ^{238}Pu; ^{235}U; ^{238}U, DU
TA-3-66	Sigma: materials fabrication since 1958; also –141 Rolling Mill, -35 Press Bldg, -159 thorium storage	^{235}U; DU
TA-3-1698	Materials Science Laboratory: processing, mechanical research	DU
TA-3-39,102	Machine shops: since 1953; Be in Bldg 39, DU in Bldg 102	DU
TA-4	Alpha Site: firing site until 1956; Material Disposal Area C	DU
TA-5	Beta Site: former firing site used extensively in 1945	DU
TA-6	Two-Mile Mesa Site: mostly undeveloped; detonator manufacturing and testing 1944-50	DU
TA-7	Gomez Ranch Site: former firing site used from 1944-47 for small explosive experiments with short-lived radionuclides	DU; unknown
TA-8	GT Site (a.k.a. Anchor Site West): gun firing sites 1943-45; explosives processing 1945-50; nondestructive x-ray testing 1950-present	^{239}Pu; ^{238}Pu; ^{235}U; DU; ^{60}Co; ^{192}Ir; ^{137}Cs; X-rays
TA-9	Anchor Site East (a.k.a. Anchor Ranch): firing areas; explosives research (active)	DU; ^{3}H
TA-10	Bayo Canyon: Radioactive lanthanum test shots 1944-61; Radioactive lanthanum radiochemistry 1944-50; site removed in 1963	^{90}Sr; DU; NU; ^{140}La
TA-11	K Site (active): implosion studies; later drop and vibration tests, dates unknown at this time	DU; ^{226}Ra, betatron
TA-12	L Site: explosives testing (1945-46); abandoned in mid-1950s	DU
TA-13	P Site: X-ray studies of explosives; later incorporated with TA-16, status unknown	X-rays, DU, ^{210}Po
TA-14	Q Site (active): explosives testing 1944-present	DU
TA-15	R Site: explosives testing; eight inactive firing sites (A-H, R44, R45); Pulsed High-Energy Radiation Machine Emitting X-Rays (PHERMEX) 1962-present; Dual-Axis Radiographic Hydrodynamics Test (DARHT) Facility	^{239}Pu; DU; ^{3}H; X-rays
TA-16	S Site (active): former explosives casting/machining operations; burning ground; Weapons Engineering Tritium Facility. Began in the 1950s	^{239}Pu; DU; ^{3}H; X-rays
TA-17	X Site (canceled)	None
TA-18	Pajarito Laboratory criticality testing 1946-present; Rover 1955-73; Hydro assembly 1957	^{235}U; ^{239}Pu; ^{240}Pu; ^{233}U; MFP; ^{131}I; polonium; neutron
TA-19	East Gate Laboratory: released to U.S. Atomic Energy Commission in 1962	None
TA-20	Sandia Canyon Site: former firing site abandoned in 1957	DU
TA-21	DP Site: former plutonium operations (DP West); uranium/polonium operations (DP East); Material Disposal Areas A,B,T,U,V; Tritium Systems Test Assembly, Tritium Science and Fabrication Facility (1945 to 1978)	^{239}Pu; ^{238}Pu; ^{240}Pu; ^{241}Pu; ^{241}Am; ^{235}U; ^{238}U; ^{210}Po; ^{227}Ac; ^{3}H
TA-22	TD (Trap Door) Site: detonator development; shops; disposal pits	DU
TA-23	NU Site: reduced firing load at TA-9 1945-50	Unknown

TA	Name and Description	Materials Involved[a]
TA-24	T Site: X-ray studies of explosives; later incorporated with TA-16	X-rays, DU
TA-25	V Site: explosives assembly; later incorporated with TA-16	DU
TA-26	D Site: storage vault and guard building 1946-48; removed in 1966	^{3}H, ^{235}U; ^{233}U
TA-27	Gamma Site: plutonium gun assembly 1945-47	^{239}Pu, DU, thorium
TA-28	Magazine Area A (active): firing site 1979; explosives storage area	DU
TA-29	Magazine Area B: explosives storage area; abandoned in 1957	DU
TA-30	Electronics Test Area: electronics testing 1945-48	Unknown
TA-31	East Receiving Yard: 1948-54 warehouses W of airport; removed 1954	Unknown
TA-32	Medical Research Laboratory: bio-research facility; 1943-54; removed in 1954; incinerator use included	Unknown
TA-33	HP (Hot Point) Site: 1948-56 shaft experiments; High Pressure Tritium Laboratory 1970s; Material Disposal Areas D, E, K	^{3}H
TA-34	New Laboratory Warehouse Area (canceled)	None
TA-35	Ten Site: Radioactive lanthanum 1951-63; Los Alamos Power Reactor Experiment (LAPRE) I/II 1950s; Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) I 1960s; laser fusion research 1974	^{3}H; ^{90}Sr; ^{140}Ba; ^{140}La; ^{235}U; DU; ^{237}Np; Pu; Po; Co; VFP
TA-36	Kappa Site: replaced TAs-9, 23, 12 in 1950; four active firing sites; nonnuclear ordnance and armor	DU
TA-37	Magazine Area C (active): explosives storage area	DU
TA-38	Monterey Site (canceled)	None
TA-39	Ancho Canyon Site: five firing points; incinerator 1955-60; photographic study of the behavior of nonnuclear weapons	NU; DU; thorium
TA-40	DF (Detonator Firing) Site: six firing points; detonator development	^{3}H
TA-41	W (Weapons Group WX) Site: engineering of nuclear components; fabrication of test materials	^{3}H; plutonium; uranium; americium
TA-42	Incinerator Site: for low-level Pu contaminated waste; abandoned 1970	All
TA-43	Health Research Laboratory: biological research 1953-70; replaced TA-32	All
TA-44	Los Angeles Shop: experimental machine shop in Los Angeles, CA 1949-58; abandoned in 1958	Unknown
TA-45	Radioactive Liquid Waste Treatment Plant (inactive): removed majority of plutonium before discharge to Acid Canyon	$^{238/239}$Pu, $^{235/238}$U
TA-46	WA Site: Rover batteries 1950-74; U isotope separation 1976-early 1980s; photochemistry research; lasers	^{235}U, ^{238}U thorium
TA-47	BR Site (Bruns Railhe): shipped materials via a railhead near Bruns Hospital in Santa Fe, 1943-58; abandoned in 1958	DU; unknown
TA-48	Radiochemistry Site: actinide chemistry and hot cell isotope production, area used for analyzing samples from weapon test shots, 1950s to present	U; TRU; MAP; MFP
TA-49	Frijoles Mesa Site: underground hydronuclear experiments 1960-61; now Hazardous Devices Team Training	^{3}H; plutonium; uranium
TA-50	Waste Management Site: treated liquid wastes before discharge to Mortandad Canyon; replaced TA-45,-35; controlled air incinerator 1976	All
TA-51	Environmental Research Site: animal exposure facility 1962; now studies of impact of waste and waste storage on the environment	^{60}Co, strontium
TA-52	Reactor Development: Ultra-High Temperature Reactor Experiment (UHTREX)	^{235}U; ^{238}Pu; ^{3}H; VFP; Kr; Xe
TA-53	Los Alamos Neutron Science Center (LANSCE)	^{3}H; ^{41}Ar; ^{7}Be; ^{11}C; ^{13}N; ^{15}O; U
TA-54	Waste Disposal Site: solid wastes; Materials Disposal Areas G, H, J, L	All
TA-55	Plutonium Facility Site (active): replaced TA-21; SNM storage, 1978 to present	^{239}Pu, ^{3}H
TA-56	Subterrene Basalt Site: melting basalt with electrically heated penetrator; abandoned in 1976	Unknown

TA	Name and Description	Materials Involved[a]
TA-57	Fenton Hill Site: Hot Dry Rock geothermal project (inactive)	Unknown
TA-58	Two-Mile North Site: experimental sciences for TA-3 programs	Unknown
TA-59	Occupational Health Site: Office of Environment, Safety, and Health offices, emergency management	None
TA-60	Sigma Mesa: Test Fabrication Facility and Rack Assembly; Alignment Complex	Unknown
TA-61	East Jemez Road: physical support and sanitary landfill	Unknown
TA-62	Northwest Site: reserved for experiments, research, buffer zones	Unknown
TA-63	Pajarito Service Area: environmental and waste management functions	Unknown
TA-64	Central Guard Facility, Hazardous Materials Response Team	None
TA-65	Not currently active or never assigned	None
TA-66	Central Technical Support Site: industrial partnership activities	Unknown
TA-67	Pajarito Mesa: former TA-12; dynamic testing area; archeological sites	DU
TA-68	Water Canyon Site: dynamic testing area with study areas	DU
TA-69	Anchor North Site: undeveloped; buffer for the dynamic testing area	Unknown
TA-70	Rio Grande Site: undeveloped; buffer for the high-explosives test area	Unknown
TA-71	Southeast Site: undeveloped; buffer for the high-explosives test area	Unknown
TA-72	East Entry Site: Protective Forces Training Facility	Unknown
TA-73	Los Alamos Airport: on-site disposal area; incinerator 1950s	All
TA-74	Otowi Tract: water wells, archeological sites, endangered breeding area	None
Miscellaneous Locations of Activities that Involved LANL Personnel		
Pacific	Nuclear tests: Marshall Islands (1945-51)	All
AK	Nuclear tests: Amchitka (Long Shot, Milrow, Cannikin) 1965,1969,1971	All
NV	Nevada Test Site: nuclear tests, Rover nuclear rocket engine program Nuclear tests, non-NTS: Fallon (Shoal); Tonopah (Faultless) 1968	All
CO	Nuclear tests: Grand Valley (Rulison) 1970; Rifle (Rio Blanco) 1973	All esp. ^{3}H; ^{85}Kr
NM	Nuclear tests: White Sands (Trinity) 1945; Carlsbad (Gnome) 1961; Farmington (Gasbuggy) 1967	All esp. ^{131}I; ^{133}I; ^{135}I; ^{137}Cs; ^{140}Ba/^{140}La
MS	Nuclear tests: Hattiesburg (Salmon and Sterling)	Unknown

[a] Key for table entries:

All = ^{239}Pu; ^{240}Pu; ^{238}Pu; ^{241}Am; ^{235}U; DU; ^{3}H; ^{210}Po; ^{227}Ac; ^{226}Ra;
DU = depleted uranium- ^{238}U;
MAP = mixed activation products (e.g., ^{41}Ar; ^{7}Be; ^{11}C; ^{13}N; ^{15}O);
MFP = mixed fission products;
NU = natural uranium;
VFP = volatile fission products;
Element names without number (e.g., plutonium, uranium) indicate isotope not specified;
a.k.a. = also known as;
SNM = Special Nuclear Material.

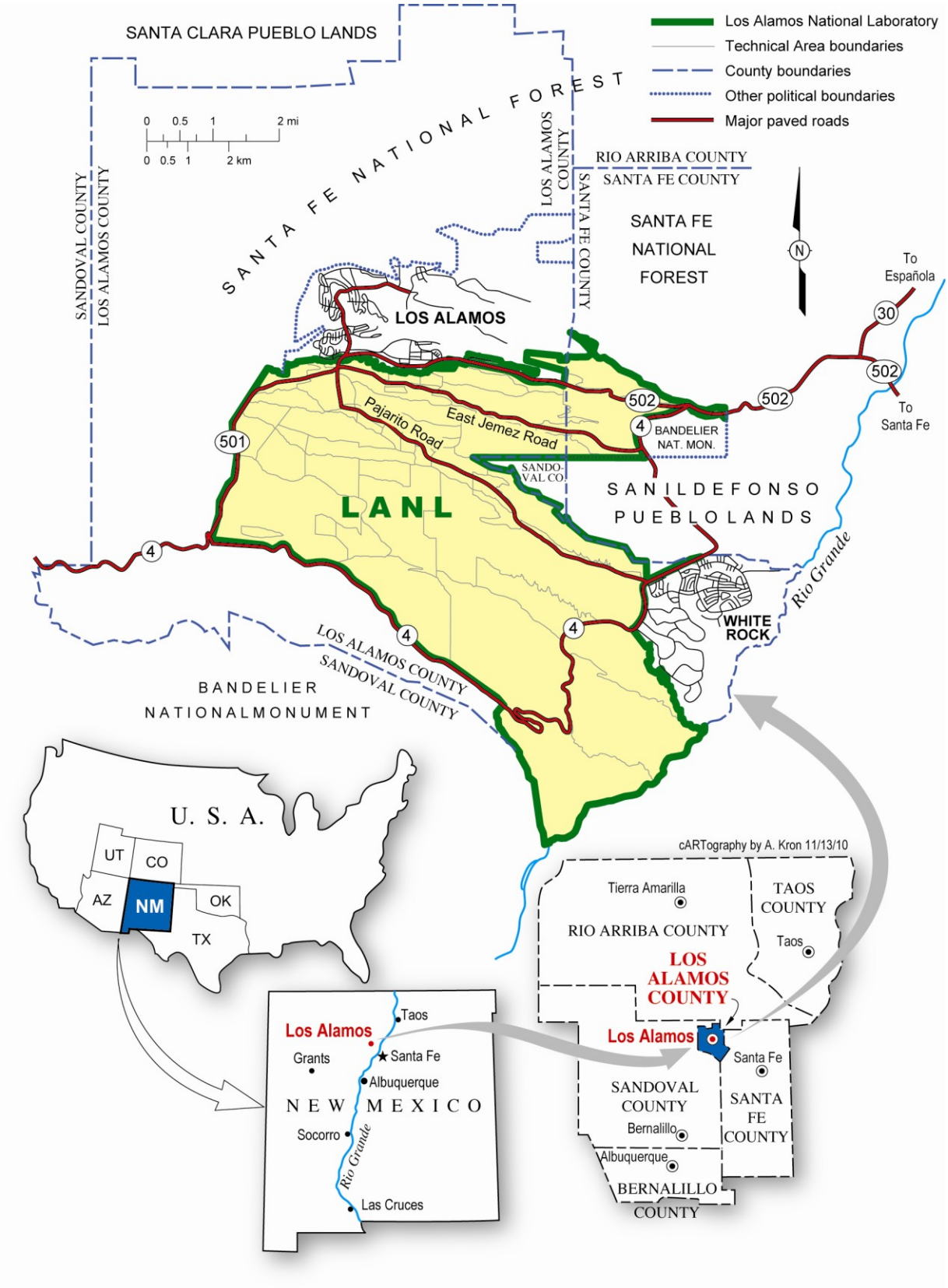


Figure 2-4: Location of Los Alamos and LANL

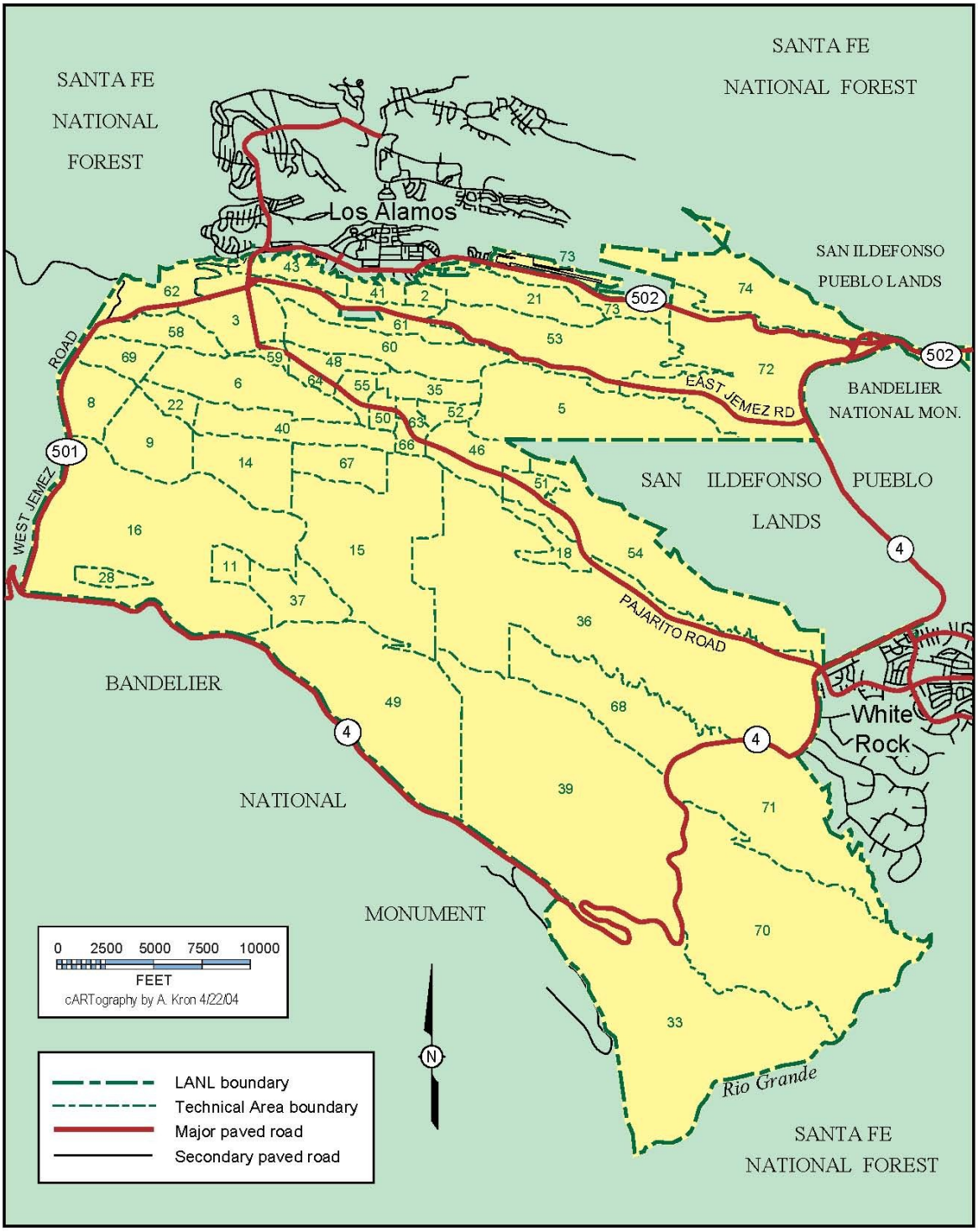


Figure 2-5: Map of LANL Technical Areas and roads

Figure 2-6: Timeline of Selected Los Alamos Operations and Activities

1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995

- D Building opens for use
- Main Pu processing performed in D Building (mg quantities at first)
- First gram-scale quantities of Pu arrived
- 2,500 experiments had been completed with 51 g of Pu
- Fire in C Shop at TA-1
- First large quantity Pu shipment arrived
- Pu for Trinity test purified
- Pu for Nagasaki bomb purified
- Pu for second combat weapon purified
- Trinity Test
- Nagasaki bombing
- Pu for first composite weapon core purified
- D Building remained in use for metallurgical R & D, analytical work, etc.
- TA-55 authorized
- Pu processed at TA-55
- Pu production conducted at DP Site (TA-21)
- CMR Building operational at TA-3, including Pu metallurgy work
- Water Boiler operated in LOPO mode at TA-2, Omega Site
- Water Boiler operated in HYPO mode
- Water Boiler operated in SUPO mode
- LAPRE I operated
- LAMPRE I reactor operated
- Omega West reactor operated
- Anchor Site West casting room operational
- LAPRE II reactor operated
- Firing Sites A & B operational
- R Site becomes main site for HE experiments
- Firing Sites C, D, E, F added
- Firing Sites G & H added
- S Site operational (high explosives casting and machining, burning ground)
- L Site operational (explosives testing)
- PHERMEX operational (explosives testing at TA-15)
- Radioactive Lanthanum (RaLa) implosion tests in Bayo Canyon
- Radioactive Lanthanum source preparation at TA-10 Bayo Canyon site
- RaLa Source prep at TA-35, "Ten Site"
- Untreated liquid radioactive waste discharged to Acid Canyon
- Polonium contaminated liquid wastes to Area U beds
- Area T adsorption beds used
- "General's Tanks" used
- TA-45 liquid waste plant operated, released to Acid Canyon
- TA-21-35 treatment plant into operation
- Area G disposal ground used
- TA-50 liquid waste treatment plant operated
- TA-21-257 treatment plant into operation
- TA-33 tritium handling facility operational
- TSTA operational at DP East
- Rover program active
- "WETF" tritium facility operational at TA-16
- LANL Rover tests in Nevada

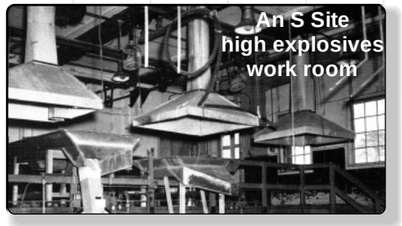
1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2009

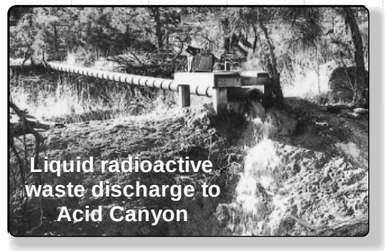

D Building in original Technical Area


The Trinity Test


DP West process buildings at TA 21


Omega Site at TA-2


An S Site high explosives work room


Liquid radioactive waste discharge to Acid Canyon

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Chapter 3: Information Gathering at LANL

The goal of the information gathering process at LANL was to identify and retrieve information relevant to off-site releases of chemicals or radionuclides, or potential health effects, associated with LANL-sponsored activities within the state of New Mexico. Information gathering began with a focus on centralized records repositories, and then progressed to records held by individual groups or divisions. The latter were selected on a prioritized basis; that is, those most likely to include information of interest were reviewed first.

Fig. 3-1. Two LAHDRA analysts review records at LANL

The principal method employed for information gathering at LANL was systematic document review (or searching). Systematic searching involves identifying the document collections that exist at a site or facility, both classified and unclassified, then progressing through those collections in an appropriate and orderly fashion until all potentially relevant documents have been reviewed. All reviews were conducted by analysts qualified to recognize information that a competent scientist would use to evaluate historical releases and/or the potential for off-site health hazards. This approach best supports the "leave no stone unturned" goal that fosters public credibility in public dose reconstruction studies. Systematic document searching can be contrasted with "directed" document searching, in which researchers identify specific information needs and go directly to the document locations or particular types of documents believed most likely to contain it. Systematic searching, directed searching, and combinations of the two approaches have been applied in dose reconstruction studies in the U.S. over the past 15 years.

Some quasi-directed searching activities were conducted at LANL as the information gathering process progressed; these consisted of re-visiting records collections that had been searched earlier in the project to capitalize on information garnered from initial searches. These subsequent search activities were not entirely directed in nature; they still maintained characteristics of systematic searching. However, they were not entirely systematic either, since they had a narrower focus than the initial search activities. Another practice employed by the project team was focused systematic searching, in which subsets of records within a given collection were identified based on some defined criteria. These subsets were then subjected to systematic search.

Throughout this section the words "record" or "document" are used to describe a number of different types of information. In this context, records or documents are not limited to physical documents, but also include materials such as electronic databases of information, microfiche records, microfilm records, photographs, video, audio recordings, and engineering drawings. In addition to physical records, other sources of information explored by the project team included interviews with past and current LANL staff members and tours of LANL facilities.

How Documents were Categorized, Summarized, and Catalogued

When a LAHDRA analyst identified a document relevant to off-site releases or health effects, he or she would then complete a Document Summary Form (DSF). The DSF provided a bibliographic summary of the document, including its location, so it could easily be retrieved again in the future if needed. Copies of documents clearly relevant to estimating off-site releases or health effects were requested. For other documents, such as those containing supporting information or otherwise not directly applicable, copies were sometimes, but not always, requested. A DSF was completed for all relevant documents regardless of whether a copy was requested from LANL.

Copies of documents requested by the project team, as well as all DSFs completed at LANL, were required to go through a review process before they could be released to the LAHDRA team. All DSFs and documents were reviewed by LANL to ensure that they did not contain classified information, personal information protected under the Privacy Act, or proprietary or legally privileged information.. If a document had been deemed Official Use Only (OUO) by its originator, the review process expanded further to include an effort to contact the originating author or organization and have the OUO designation removed. In all but a few cases, such requests were accepted, and the documents were released to the public. One of the LAHDRA project's aims was to place all of the material retrieved from LANL in the public domain. There were a few cases, however, where OUO restrictions could not be removed from documents desired by the project team. In these instances, the documents were provided to the project team for its use, but they remained subject to appropriate OUO controls.

After receipt from LANL, each DSF and associated document (if any) was assigned a LAHDRA Repository Number, and the information from the DSF was entered into a project information database. The database fields were the same as on the DSF. The Repository Number was simply a sequential number used for indexing the database entries. Documents were scanned to Portable Document Format (PDF) files and indexed using Optical Character Recognition (OCR) software to provide full-text,

searchable electronic versions. The PDF files were linked to each database record so a user could access the document associated with an entry.

The project information database, which will be described later, was provided to a limited number of public libraries in northern New Mexico and Albuquerque. It was updated periodically as information was added. In addition, copies of documents retrieved from LANL were made available to members of the public at the Zimmerman Library at the University of New Mexico in Albuquerque.

The LAHDRA Document Summary Form

The DSF was revised several times during the information gathering process. A copy of the latest version, Revision 7, is shown in Fig. 3-2. Most of the entries on the DSF are self-explanatory. However, two that are of particular interest are described here for completeness.

Item Number/Other Identifier

This field was added later in the project to be used in conjunction with creation of the Document Request Log, which will be described later. A separate log was created for each document collection being searched. For each log sheet, entries were given a sequential item number. The item number was entered on the corresponding DSF so it and any associated copies could be tracked through the review process. The item number allowed copies of documents to be readily associated with the corresponding DSF if the two became separated.

CDC Document Category

Analysts selected one of three categories for a document using the criteria below:

Category 1. Documents that a competent scientist would use in estimating off-site releases or their health effects from operations at LANL or other LANL-sponsored operations within the state of New Mexico (such as the Trinity test). Examples of Category 1 documents include effluent monitoring data, accident reports with estimates of releases, release point information, or results of environmental monitoring performed near locations where people lived or recreated.

Category 2. Documents that contained supporting or confirming information that could be useful for estimating off-site releases or health effects from operations at LANL or other LANL-sponsored operations within the state of New Mexico. Examples of Category 2 documents include historical descriptions of site activities, notebooks for relevant operations, or process flow sheets.

Category 3. Documents that could be used to estimate or confirm off-site releases or health effects from nuclear weapons complex sites outside of New Mexico or from operations sponsored by groups other than LANL at non-LANL sites within New Mexico (such as Sandia National Laboratory).

Item Number/Other Identifier	OFFICE USE ONLY					
	S7 Initials	S7 Review Date	Page Count	Entry Date	Initials	Rep. No.
DOCUMENT TITLE						
AUTHOR(S)						
DOCUMENT NO.				PROJECT		
PUBLICATION DATE: _____ Estimated? ☐	DATA TIME PERIOD: START _____ END _____ Estimated? ☐ ☐					
ORGANIZATION(S)	TECHNICAL AREA(S)					
DOCUMENT TYPE: ☐ Box ☐ Document ☐ Electronic ☐ File Cabinet ☐ Microform ☐ Notebook ☐ Photo/Dwg.						
CDC DOCUMENT CATEGORY: 1 2 3 DOCUMENT REQUESTED? ☐ Complete ☐ Partial ☐ None						
ORIGINAL LOCATION OF DOCUMENT: ☐ Litigation Support Database _____ ☐ LANL Records Center _____ ☐ LANL Archives _____ ☐ LANL Reports Library _____ ☐ Other _____						
POINTS OF CONTACT FOR DOCUMENT 1. 2.						
KEYWORDS: Atmosphere, Biological, Chemical, Chronic Release; Design, Effluent, Environmental, Episodic Release; Ground Water, Operational, Radiation, Radionuclide; Surface Water, Terrestrial, Uncertainty, Waste Disposal. Other:						
DOCUMENT ABSTRACT: Original? ☐						
ANALYST COMMENTS						
ANALYST:	DATE REVIEWED:					

Fig. 3-2. The LAHDRA Document Summary Form (DSF)

In contrast, documents about activities by LANL personnel that occurred beyond LANL's boundaries but within New Mexico (such as the Trinity test) would fall under Category 1 or 2. Documents concerning operations at foreign nuclear weapon sites or nuclear power plants (foreign or domestic) were not Category 3 material, since such activities did not fall within the responsibility of the U.S. Department of Energy or its predecessor agencies. In general, copies were not requested for Category 3 documents, but there were cases when copies of Category 3 material were obtained.

Table 3-1 provides a summary of how documents were categorized based on their descriptions of activity location and sponsorship. A document could only be assigned one category number.

Table 3-1: Assignment of document category based on activity sponsor and location

Activity's Sponsor	**Location of Activity**		
	At LANL	Within New Mexico but not at LANL	Weapons Complex Site Outside of New Mexico
LANL	Category 1 or 2	Category 1 or 2	Category 3
Others	Category 1 or 2	Category 3	Category 3

The Document Request Log

Toward the later stages of the project, the information gathering process was augmented to include the use of a log sheet called the document request log. Its purpose was to record information about each DSF and any associated document copies generated or requested by the project team. Individual log sheets were used for each specific LANL records facility or collection where review activities were performed.

The document request log provided a formal record of material requested by the project team. It was used to track items (DSFs and documents) from the time they were requested until they were received. The request log became necessary because of significant delays that would sometimes occur between request and receipt. In some cases, material would get lost in the review process, so the request log provided a means for identifying and retrieving missing material.

A separate request log was created for each document collection or facility being searched. Each entry on a given log was assigned a unique item number. Item numbers were used as a reference when tracking the progress of material through the review process and for associating documents with DSFs in cases where they were not reviewed together. The fields on the log sheets varied somewhat depending on the records facility where they were used, but they all included fields for the document title, page count, location, accession numbers or other identifiers, and so forth. A request log entry was made for each DSF

regardless of whether the underlying document was copied so that there would be a complete record of everything the project team identified as relevant within a given document collection. The request log also included fields for use by the classification reviewers to indicate that they had reviewed each document, and whether it had been declassified, redacted, etc.

The Project Information Database

The bibliographic information from each DSF as it was received from LANL was entered into a Microsoft® Access database created for that purpose. The basic structure of the database was defined by the CDC at the outset of the project. As each DSF was entered into the database, it was assigned a unique Repository Number; a Repository Number was simply a sequential number used for reference and indexing. Following data entry, the DSFs and associated documents were filed by Repository Number.

As the size of the document collection grew and scanning technology matured, a decision was made to scan all of the documents received from LANL to PDF files. OCR software was used to create a full-text searchable image, within the constraints of the image quality of the original. The OCR process is not 100% reliable, however, given the poor quality of some of the documents. It was also not capable of translating handwritten documents into text.

Fig. 3-3 depicts the progression of a document from a handwritten DSF through entry of the DSF information into the information database, and finally to the creation of a searchable PDF image file.

The project database, including the searchable image files, was made available to the public at three regional libraries within New Mexico: the Zimmerman Library at the University of New Mexico in Albuquerque, the Mesa Public Library in Los Alamos, and the Northern New Mexico Community College library in Española. Users may search the bibliographic information from the DSFs and perform full-text searches of the document images. As mentioned above, the OCR process can miss words or text in poor quality originals, so it is recommended that users utilize both full-text searches and searches of the DSF information (i.e., fielded or filtered searches) to find information of interest.

In addition to the Access-based database, the project team developed an additional, versatile Web-based application for searching the database and scanned documents. The application, called DocSleuth, was hosted by ChemRisk, and was available over the Internet to project team members and other selected individuals. DocSleuth employs sophisticated indexing technology to a flat-fielded version of the project database. The database was re-indexed periodically as information was added. DocSleuth allows global or fielded searches, or combinations of these, and provides a comprehensive tool for garnering

information from the large collection of material retrieved from LANL. An image of the DocSleuth search screen in presented in Fig. 3-4.

.

Los Alamos Document Summary Form | Document Requested: ☐ Complete ☐ Partial ☐ None

DOCUMENT TITLE: Facts about Los Alamos Scientific Laboratory of the University of California

DOCUMENT NUMBER: none | PROJECT:

AUTHOR (S): not identified.

PUBLICATION DATE: October 1964 | DATA TIME PERIOD: start: _____ stop: _____

ORGANIZATION: | TECHNICAL AREA:

CDC DOCUMENT CATEGORY: (1) 2 3 | DOCUMENT TYPE: ☐ Box ☐ Document ☐ Computer file ☐ File cabinet ☐ Interview ☒ Microfilm ☐ Notebook

ORIGINAL LOCATION OF DOCUMENT: ☐ Online _____

☐ LANL Research Library ☐ LANL Reports Collection ☐ ESH Records Center _____

☒ LANL ARC _____ ☐ LANL Archives _____ ☐ Other _____

POINTS OF CONTACT FOR DOCUMENT:
1. Roger Meade 2. Chris C'de Baca

KEYWORDS: (circle or write in)

Atmosphere	Biological	Chemical	Chronic Release
Design	Effluent	Environmental	Episodic Release
Ground Water	Operational	Radiation	Radionuclide
Surface Water	Terrestrial	Uncertainty	Waste Disposal

Other _____

Document Abstract: Original ☐

Provides summaries of research and development programs at LASL, including weapons development and testing, Rover, plasma thermocouple, Project Sherwood, reactors, critical assemblies, theoretical physics and mathematics, Vela Program, accelerators, explosives research, health research, chemistry & metallurgy research, and cryogenics. Includes a chronology of LASL "firsts" from 1943 to 1964. Includes some historical facts about LASL and the Los Alamos community.

ANALYST'S COMMENTS ON DOCUMENT'S RELEVANCE TO DOSE RECONSTRUCTION:
Useful historical background, employment levels, housing details.

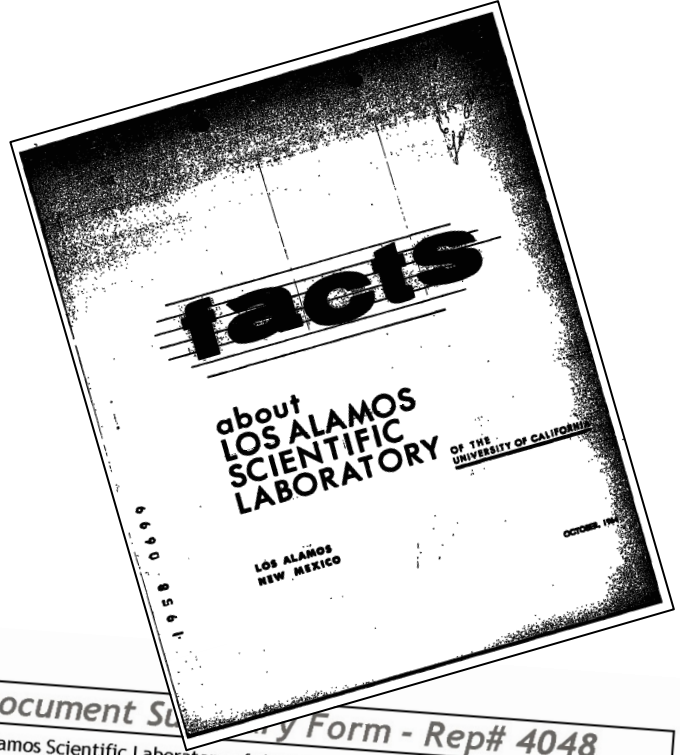
ANALYST: T-E. Widner | DATE REVIEWED: 12/3/2003

S7 Reviewer Initials: | S7 Review Date: | Page Count:

Archival Use Only

Repository#: 4048 | Date Entered into Database: 12/4/03 | Signature:

REV 5: 2/7/03 Los Alamos Historical Documents Retrieval and Assessment Project



LAHDRA Document Summary Form - Rep# 4048

Title: Facts About Los Alamos Scientific Laboratory of the University of California

Author(s):

Document Number: | **Project(s):**

Publication Date: 10-31-1964 | **Data Time Period:** 01-01-1964 - 10-31-1964

Organization(s): | **Technical Area(s):**

Document Type: (2) Document | **CDC Document Category:** 1

Top Level Location: LANL RC | **Location:** Unknown

Keywords: operational

Document Abstract: Provides summaries of research and development programs at LASL, including weapons development and testing, Rover, plasma thermocouple, Project Sherwood, reactors, critical assemblies, theoretical physics and mathematics, Vela program, accelerators, explosives research, health research, chemistry and metallurgy research, and cryogenics. Includes a chronology of LASL "firsts" from 1943 to 1964. Includes some historical facts about LASL and the Los Alamos community.

Analyst Comments: Useful historical background, employment levels, housing details.

Analyst: Thomas Widner | **Date Reviewed:** 12-03-2003

Date Entered: 12-04-2003 | **How Much on File?:** Complete

Los Alamos Historical Document Retrieval and Assessment Project

Fig. 3-3. Original DSF, DSF printed from DocSleuth, Original Document PDF

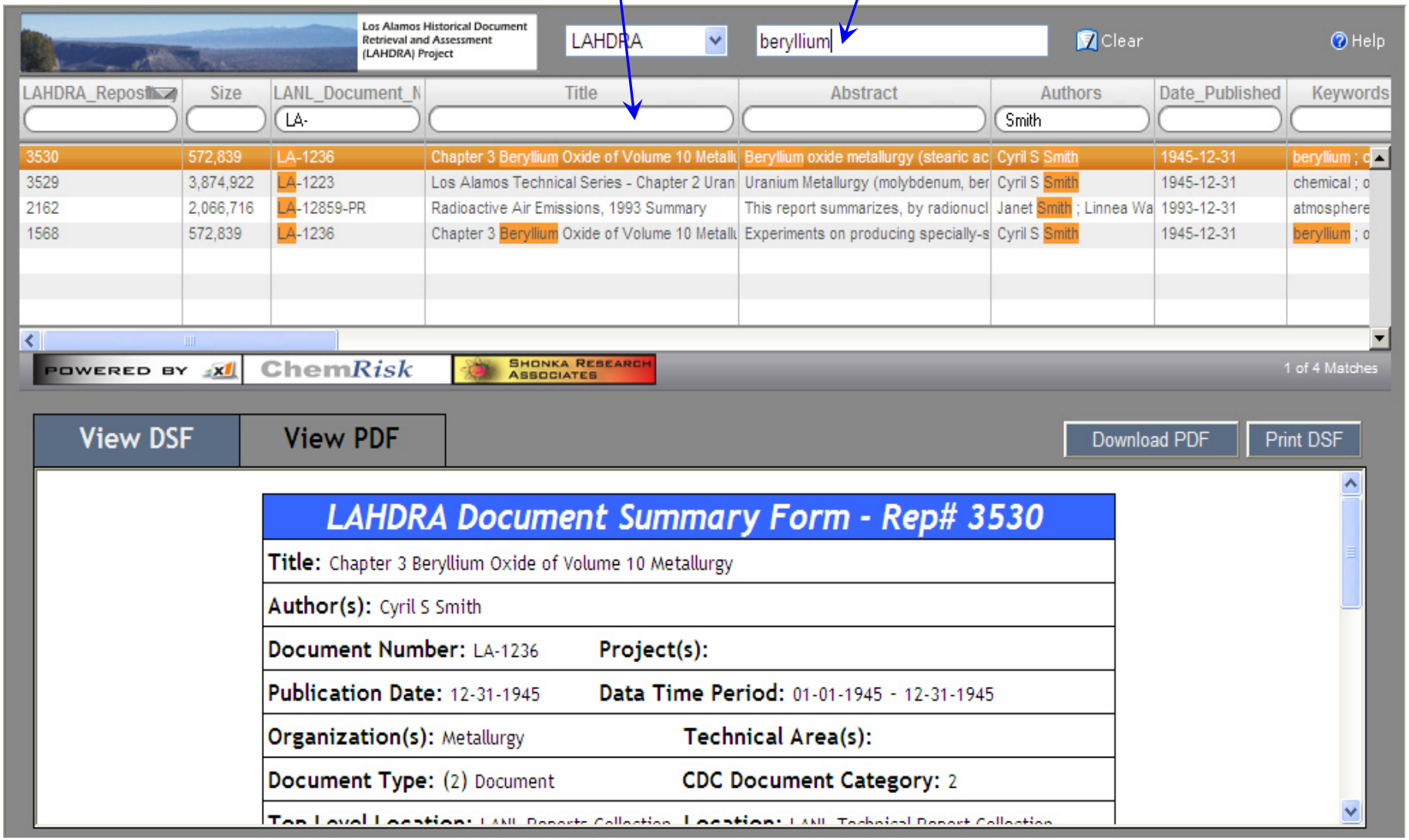


Fig. 3-4. The search screen of the LAHDRA DocSleuth database

Public Reading Room for Documents Obtained by the Project Team

The LAHDRA document repository contains paper copies of documents obtained from LANL by the project team. As of this writing, the repository contains over 250,000 pages of documents, filed under 8,000 Repository Numbers. A duplicate set of the documents is available at the Zimmerman Library at the University of New Mexico in Albuquerque (Fig. 3-5). This location was selected as the official Public Reading Room for the LAHDRA project.

Fig. 3-5. Dan Barkley of UNM discusses project records at Zimmerman Library in Albuquerque with CDC project staff

The Zimmerman Library is located on the University of New Mexico's main campus. The library's Government Information Department is a regional depository for government documents. Documents can be requested at the information desk, and photocopies can be made at a nominal cost using copiers located in the immediate area.

Directions to the Public Reading Room at the University of New Mexico:

Head east from the Central Avenue exit from I-25. Continuing east on Central Avenue, pass through the signal at University Avenue. UNM will be on the left. The third light after University Avenue will be Stanford Drive. Take a left on Stanford Drive to enter the UNM campus. Take another left at the "T." On the right will be Visitor Parking. After parking, head north and slightly west across campus. Zimmerman Library is just northwest of the Student Union Building. The Government Information Department is located in the basement of the library.

Contact: Dan Barkley, phone: (505) 277-7180; barkley@unm.edu

Restrictions on the Project Team's Access to Certain Categories of Information

Accessing and reviewing documents at Los Alamos National Laboratory has been more difficult than in any similar project conducted at other DOE sites that have been subjects of dose reconstruction investigations. The LAHDRA project was impacted by several events at LANL, unrelated to LAHDRA activities, which resulted in stand downs of Laboratory operations and the subsequent implementation of increasingly restrictive security measures. Initially, these developments severely impeded the team's

ability to complete its review, but, over time, solutions were put in place that allowed the team to complete its work in concert with increased information security measures.

When the project began, project team members who held the requisite security clearance levels were not restricted in their access to classified information in support of systematic search activities. A few years into the project, however, following some highly-publicized information security issues at LANL and a stand down of its operations, LANL enacted new security practices that encumbered the project team's access to classified documents. These new security practices included denying the project team access to specific types of information (discussed below) and requiring analysts to have permission from document owners before being allowed to review classified information. The latter constraint was a particular problem, especially in the classified reports collection, in which many reports were issued by organizations other than LANL, many of which no longer existed. In an effort to meet this new security requirement, LANL requested that project team members review reports by their titles alone. Doing so was problematic, however, since, in many cases, document titles are not a reliable means of identifying relevant content. Still later, LANL determined that it was not authorized to grant the project team "need to know" status for documents issued by organizations other than LANL, which was a reversal from how LANL staff had been operating up until that time. Additional impediments included stricter limits on the number of project team members who could work in a given location at one time, and requiring that documents be pre-screened for "deniable category information" before team members could review them. This new requirement presented two constraints. First, the requirement for pre-screening meant the project team could only work as fast as the LANL hired contractor could do the screening. Second, the contracted screeners counted against the total number of people the project team could have working in a given area.

In February, 2005, after a number of iterations between DOE, LANL, CDC, and the project team, a number of the security restrictions that had been preventing the project team from conducting systematic review activities were relaxed. This relaxation left the excluded categories of information and the associated requirement for pre-screening in place as the mechanism for addressing concerns over "need to know" issues that had been raised during internal and external reviews of LANL's security practices.

Table 3-2 below summarizes the information categories to which project team members were denied access. These restrictions meant that classified information to be reviewed by the project team first had to be reviewed by an authorized individual to ensure that no deniable information was present. If deniable information was present, a general description of the contents was provided, to the extent practical, to allow the project team to make a judgment as to whether the material potentially contained relevant

information. In general, this process proved to be a workable, though time-consuming, solution. In the event that the project team felt denied documents could contain relevant information, a process was available whereby an appropriately-cleared CDC employee could review the material. The reason for the distinction between CDC employees and the CDC contractor (the project team) was unclear, since all of the classified material pre-screening was being performed by LANL hired subcontractors.

Table 3-2. Categories of information withheld from the LAHDRA team by LANL

Nuclear Weapons Design Information– documents relating to nuclear weapon design, such as weapon component blue prints, drawings, or other schematic or graphical design information.
Sigma 14 Information– concerns the vulnerability of nuclear weapons to deliberate, unauthorized nuclear detonation.
Sigma 15 Information– concerns the design and function of nuclear weapons use control systems, features, and their components, including using control information for passive and active systems.
Sensitive Compartmented Information (SCI)– includes information determined pursuant to Executive Order 12958 or any predecessor order to require protection against unauthorized disclosure and is so designated; includes conventional weapons, security systems, foreign relations, and information regarding intelligence sources and methods.
Special Access Program (SAP) Information– deals with programs that are judged to require access limitation beyond that of the three-tiered classification system (Confidential, Secret, and Top Secret). These include programs within the Departments of Energy, Defense, and State. For example, the Congressional Emergency Relocation Site located under the Greenbriar Hotel in West Virginia, built to house Congress and key staff in the event of a national emergency, was designed, constructed, and maintained as a SAP for over 30 years until declassified in 1994.
Foreign Government Information (FGI)– includes information provided to the U. S. Government by a foreign government or governments, an international organization of government, or any element thereof, with the expectation that the information, the source of the information, or both, are to be held in confidence.
Unclassified Sensitive Vendor Proprietary Information– includes information that is deemed "sensitive unclassified," and touches on areas such as trade secrets and privileged or confidential commercial or financial information.

Summary of Information Gathering Activities for Specific Document Collections

Document review activities began with an emphasis on LANL's large, centralized records repositories, and then progressed to include records held within specific divisions or groups. Systematic searching was the predominant method used for all information gathering activities at LANL. For the larger, centralized repositories, systematic search activities generally occurred over multiple stages. After an initial

systematic review, follow-up review activities were performed as needed to evaluate information accessioned since completing the initial review.

Centralized Repositories

The LANL Records Center

The LANL Records Center was a principal focus of the information gathering task at LANL. This facility initially was housed in Building 1001 in Technical Area 21 (TA-21-1001). Later in the project, the Records Center was relocated to the National Security Sciences Building (NSSB). The project team performed records review activities in both locations. In addition to the Records Center, the LANL Archives was also housed in Building TA-21-1001 until the time it, too, was relocated to the NSSB. The Archives collection was stored, maintained, and managed separately from the Records Center's holdings, and review of that facility was conducted separately from that for the Records Center. The systematic review of the Archives is discussed later in this chapter.

The original LANL Records Center was a 15,000 square foot building located at 180 6th Street in Los Alamos. The Records Center's function is to receive and catalog records from the various LANL groups and divisions, place and maintain them in retrievable storage, and disposition them in accordance with DOE retention and disposition guidelines and other associated requirements (such as the moratorium on destruction of records deemed pertinent to epidemiological studies).

Building TA-21-1001 (the original Records Center) was sub-divided into six "bays" denoted A through F. It also included a seventh bay, denoted G-Bay, located in a separate building (TA-21-1002) behind the primary facility. The primary facility, Building TA-21-1001, was a designated Vault-Type Room, and included classified holdings. The records stored in G-Bay were considered unclassified for access control purposes. The Records Center holdings were stored in bays B, C, E, F, and G. Each bay contained a number of rows consisting of either tall (10-drawer) filing cabinets or shelving. Shelving and file drawers from the original Records Center are shown in Fig. 3-6 through Fig. 3-9. The file drawers were used primarily to store paper records. The shelving was used to hold records contained in standard, one cubic foot storage boxes. A number of mobile storage units were also used to house media such as microfiche and microfilm. Fig. 3-10 and Fig. 3-11 show storage and review of microfilm records in the original Records Center. Each bay typically contained a mix of different types (formats) of records and records storage media/containers. The tops of the rows of file cabinets, for example, were used to store boxes and large-sized media such as drawings and blueprints.

Fig. 3-6. Boxes of documents on shelves in the LANL Records Center in 2005

Fig. 3-7. Document review in the LANL Records Center

Fig. 3-8. File drawers used for document storage in the LANL Records Center in 2005

Fig. 3-9. Review of notebooks in a Records Center drawer

Fig. 3-10. One of numerous drawers of microfilm in the LANL Records Center in 2005

Fig. 3-11. Review of microfilm in the LANL Records Center in 2005

All materials accessioned by the LANL Records Center are assigned a Transfer Record (TR) Number. TR Numbers are assigned sequentially, and are the principal means of identifying, locating, and tracking material in the center. Locations of records in the original Records Center were referenced using a "bay-row-shelf" nomenclature, where "shelf" could have been any number of storage locations, such as a file drawer or a specific box in a vertical stack of boxes. Thus, the location "B-1-2" would refer to material location in B-Bay, Row 1, Location 2.

The LANL Records Center had been operating near its storage capacity for some time, and the space shortage resulted in records frequently being relocated, reconsolidated, transferred to Federal Records Centers, or otherwise dispositioned to free up space to accommodate newly-accessioned material. In 2005, the Records Center began the process of relocating to the NSSB. Many of the records were relocated to the NSSB, and many others were transferred to Federal Records Centers.

The layout of the Records Center in the NSSB is similar to that in the previous facility, though without the individual bays. Otherwise, the storage systems were similar, and, in fact, the file drawer storage units were physically moved from the old facility to the new one.

The systematic search of the Records Center may be described as having occurred in four distinct phases: initial search activities (up to the work stoppage in 2003 prompted by LANL security issues), an interim period, resumption of systematic search activities following the work stoppage, and follow-up review activities after the Records Center relocation to the NSSB.

Initial Systematic Searches of the Records Center: February 1999 – October 2003 – The initial systematic search for relevant material in the LANL Records Center began in February 1999 and continued until October, 2003. To facilitate identifying what had and had not been reviewed, records were marked with one of two rubber stamps. One stamp was used to identify records that contained no information pertinent to off-site releases or health effects (Fig. 3-12):

✓CDC/NCEH
REVIEWED
(in green ink)

The other stamp was used to identify boxes or drawers that did contain relevant information; that is, at least one document deemed to fall under Category 1, 2, or 3 (Fig. 3-13):

★ CDC/NCEH ★
DO NOT DESTROY
(in red ink)

Fig. 3-12. A Records Center drawer with a green "CDC Reviewed" stamp affixed

Fig. 3-13. A Records Center box marked with red "Do Not Destroy" stamps

For records stored in boxes, the outside of the box was stamped. For records stored in drawers, an adhesive label was stamped and affixed to the drawer. Originally a log entry was made identifying everything that was reviewed. These logs, referred to as "box logs," included the document category assigned to the material (i.e., Category 1, 2, 3, or 4), its TR Number, location, the name of the analyst who performed the review, and the review date. This information was recorded for all material, regardless of whether it contained relevant information. If material was selected for copying, an additional entry was made in a separate log identifying the material by its TR Number and location. The purpose of this "review log," as it was known, was to provide the classification reviewers a current listing of what they needed to review and where it was located. This "review log" was a predecessor to the formal document request log initiated later in the project. Material to be copied was flagged using self-stick notes or the equivalent to make it easier for the classification reviewers or others to find later. Once material was either confirmed to be unclassified or properly redacted, it was copied and forwarded for an additional series of reviews to confirm that it could be released to the public. The purpose of this subsequent review was to screen for information protected under the Privacy Act, proprietary, and/or attorney-client privileged, etc. The review log served as a tool to identify material that still needed to be copied, was in need of classification review, including or had been forwarded for the second part of the review process.

Early in the initial review it became apparent the tools and methods originally specified for tracking progress and identifying material that had and had not been reviewed were inappropriate for a facility like the Records Center. The large volume of the material, coupled with its dynamic nature (i.e., high turnover), meant handwritten logs were of little use. Boxes and drawers that had been stamped by the project team were often re-used to store material that had not been reviewed. The presence or lack of one of the stamps, then, was of limited value. Further, the ever-changing number of storage locations and constant in-flux of new material made estimating a completion percentage problematic, and presented a task that was open-ended. A more reliable method was thus needed to keep track of the systematic review of the Records Center.

An electronic database of the Records Center's holdings was created to allow tracking of what had and had not been reviewed by TR Numbers. The project team adapted the database used by the Records Center staff to track its holdings. Tables, fields, and LAHDRA-specific search criteria were added as needed, including an electronic version of the box log. The box logs and accession/turnover information provided by the Records Center staff provided the two sources of data used to maintain the database. As long as the database was kept current in terms of records locations and TR Numbers, any discrepancies

between it and the handwritten box logs gave an immediate indication of either an error in the log or of material that had been moved or otherwise dispositioned. This process greatly simplified the task of tracking material that had and had not been reviewed, even for cases where the same locations required review multiple times because of records turnover.

In conjunction with implementing the database for tracking progress, a cutoff accession date was established to define a fixed end point for the initial systematic review of the Records Center. The cutoff accession date chosen was December 31, 1999. The last Transfer Record assigned prior to this date was TR Number 13779. Materials in the Records Center with a TR Number of 13779 or less were thus targeted for review under the initial systematic review. Records accessioned after January 1, 2000 were addressed in subsequent review activities. The cutoff accession date was only applied to hardcopy records.

The database used to manage and track the initial systematic review of the LANL Records Center was not used for microform records (that is, microfilm or microfiche). These materials did not suffer from the turnover problems that hindered the review of the hardcopy records, so the review of the microform records was managed and tracked in a manner more consistent with what was originally conceived. Small red or green adhesive dots were applied to microfilm cassettes in lieu of the rubber stamps to indicate material that had been reviewed. For microfiche records, the rubber stamps were applied to either the sleeve storing the media (for individual microfiche records), or to the storage container (such as the front of a drawer) if the volume of records was large.

Interim Search and Retrieval Activities: September, 2004 to March, 2005 – A work stoppage prompted by security issues at LANL halted systematic search activities at LANL in October, 2003. A large backlog of material selected by the project team for copying and release to the public had accumulated. An interim task to get this material copied, reviewed, and released began in September, 2004.

A listing of outstanding material from the initial systematic review was compiled so it could be located and placed into the review process. By the end of March, 2005, all of this material had been located and submitted for review. By the middle of May, 2005, all of the outstanding material selected by the project team during its initial review activities in the LANL Records Center was in the project's repository.

Paralleling the task to close out the backlog material during this interim period, a CDC staff member made several trips to the LANL Records Center and the LANL Reports Library to close out some other outstanding items from the initial search activities. Specifically, the review of hardcopy (i.e., non-

microform) records at the Records Center and a subset of classified reports in the Reports Library were completed.

Resumption of Systematic Search Activities: February 2005 – Systematic search activities at the LANL Records Center (and for the project as a whole) resumed in February, 2005. Review of hardcopy records accessioned through 1999 had been completed, so the focus upon resumption of systematic searching was completion of the microform records (i.e., microfilm and microfiche). Time was of the essence, given the pending relocation of the Records Center to the NSSB.

When work resumed, there were approximately 4,100 cards of microfiche and 2,700 rolls of microfilm in the Records Center remaining to be reviewed. Systematic review of the microfiche was completed by mid-March, 2005. Systematic review of the microfilm (and thus the LANL Records Center itself, for the time being) was completed in early June, 2005.

The resumption of systematic review activities saw a significant improvement in throughput over that experienced previously. This improvement was due to a number of important changes that were made to the document review and release process, including analysts being allowed to disposition non-relevant material by title alone, and to copy relevant documentation as it was identified. Being able to copy the material as it was identified and attach it to the DSF eliminated problems suffered previously with obtaining copies of what the analysts had selected. Another important, but unfortunately, short-lived change was the near-full-time availability of a contractor who could not only perform the requisite classification reviews, but also authorizethe declassification of material when appropriate. These changes led to improved throughput of systematic review activities, including short turnaround times between when relevant material was identified and when it was received by the project team. Further, adopting the document request log during this time made it easier to confirm that everything the project team had requested was received, and to resolve any discrepancies.

Follow-up Reviews in the NSSB – Review of records accessioned after December 31, 1999 took place after the Records Center had completed its relocation to the NSSB. This review was performed by reviewing the information on the individual TRs and identifying records of interest. The scope of this review was limited to records that were stored at LANL; that is, it did not include records that had been transferred to the Federal Records Center.

The LANL Archives

Initially, the LANL Archives was housed primarily in A-Bay of Building TA-21-1001. Some materials (motion picture reels, for instance) wre housed in B-Bay, and additional materials (including some that

had not yet been formally accessioned) were stored in G-Bay in Building TA-21-1002. These locations are where the Archives records were maintained when the project team completed its initial systematic review (with the exception of film (motion picture) and video records) in early May, 2006. Subsequently, the Archives were relocated to the new NSSB in TA-3. Once operating in its new location, the project team performed follow-up activities to revisit document collections previously reviewed and reviewed any records accessioned since the completion of the initial systematic review. The second look at documents previously reviewed was prompted by insights gained from the study of the information obtained from the initial review.

In general, the Archives records were organized into individual folders, which were stored in boxes (see Fig. 3-14 through Fig. 3-17). The boxes and folders were constructed of acid-free paper, making them suitable for archival storage. Most of the boxes were of a clamshell design, allowing easy access to the folders inside. Other types and sizes of boxes were used for some large or odd-sized media (microform records, etc.). Some non-paper records were stored in cases or cans on Archives shelves (see Fig. 3-18 and Fig. 3-19).

Archives records were organized into collections, with a collection consisting of records covering a common subject area (e.g., an individual's memoirs, the records of a particular facility or group, etc.). A collection could be one box, or could span hundreds of boxes. Each collection was assigned a unique collection number, consisting of the year the material was accessioned and a sequential number starting with 001 for each year. Boxes were numbered sequentially within each collection, and folders were numbered sequentially within each box. Each collection had an inventory listing that gave a brief description of the contents of each folder.

The LANL Archives was a largely static, well-organized collection of records. That fact, plus the availability of inventory listings, provided a framework for systematic document searching that did not exist at other centralized repositories. The project team began systematic review of records in the LANL Archives in June, 2005. The first step in the review process was to obtain the inventory listings for each collection. The Archives staff provided these listings to the LAHDRA project office, which broke them up into "Pages." The complete listings were broken up into 52 Pages, with a given Page consisting, generally, of hundreds of pages of inventory. (LANL's choice of "Page" as its nomenclature for the inventory listings was sometimes a source of confusion for those not yet familiar with it. A "Page" of inventory listings covered many different collections, and was by no means just a single page of information.)

Fig. 3-14. Moveable shelving units in the LANL Archives in 2005

Fig. 3-15. Boxes used to store LANL Archives materials

Fig. 3-16. Boxes used for storage of archived material

Fig. 3-17. A classification officer preparing to review documents selected by LAHDRA analysts

Fig. 3-18. The LANL Archives contain paper documents, audio tapes, video tapes, and microfilm

Fig. 3-19. The LANL Archives includes classified and unclassified motion picture films and videos

The inventory listings were placed in three ring binders and provided to the project team. Project analysts then went through the listings and selected material for review based on the descriptions given. The detail in the inventory listings allowed this selection process to be performed at the folder level rather than the box level. The selection process was rather broad, as often the inventory list description did not make it immediately apparent what the material actually was. In such cases, the material in question was always selected for review. Once this selection process was completed, approximately 28,235 folders had been selected for review, which equalled approximately 25% of the total folders in the Archives at that time.

In addition to the records selected by the project team for review, a random sampling of 1% of the folders in the Archives was also performed. The purpose of this sampling was to select material to be reviewed by the analysts to act as a check on both the project team's document selection process and on the accuracy of the Archives inventory listings. The 1% sampling process did not indicate any problems with the material selection process or the Archives' inventories.

The review of the material selected by the project team, in general, proceeded one page at a time. A set of boxes from a given collection was pulled, and each folder selected from within those boxes (either by the analysts or via the random selection process) was reviewed. Once the review was completed, the appropriate stamp (red or green) was applied to the box and the analyst indicated that the material had been reviewed by initialing and dating the inventory listing for that folder. This process continued until the Page was completed. Deviations from this process were made as needed, such as advance review of excluded material (discussed below), or completing the review for all material in G-Bay (regardless of its Page listing). In the latter case, a priority was made to complete the review of material stored in G-Bay under favorable weather conditions. G-Bay was a seldom-used facility with limited climate control, so both LANL and the project team wanted these reviews completed after the summer and before the winter. Review of Archives material in G-Bay (including material not yet accessioned) was completed around the middle of October, 2005.

Prior to review by the project team, all of the material selected (either directly or through random sampling) had to be pre-screened for excluded categories of information by authorized individuals. For the Archives, information determined to be excluded by LANL's reviewers was dispositioned by an interactive discussion between the reviewer and a project analyst (information was excluded at the folder level). The reviewer gave the analyst a basic description of the contents of the folder and the reason for withholding the material from detailed review. This process gave the analysts enough information to make an informed decision as to the relevance of the material for the LAHDRA project. Little of the

material selected for review in the Archives was excluded, and none of the material that was was thought to contain relevant information. Much of the excluded material came out of the random selection process, and was not material selected by the project team. The project team went through and addressed most of the excluded material in advance so it did not impede the progress of the systematic review.

As previously discussed, follow-up review activities were completed for hardcopy Archives records following the Archives relocation to the NSSB. In 2007, the project team was provided a listing, several hundreds of pages in length, of films and video tapes held in the Archives collection. This listing was reviewed during 2007 and 2008, and potentially relevant titles were selected for review. In early 2009, a list of 84 titles was submitted to LANL with a request that they be made available for review. It was determined that there was significant duplication within the list, that some of the films were old and brittle, and that viewing would be problematic for some of the requested titles. A plan was devised to review as many films as possible during the remaining visits to LANL in 2009, budget permitting.

The LANL Reports Collection and Research Library

Initially, the LANL Reports Collection was housed in a vault facility located beneath the LANL Research Library. Along with the Records Center, Archives, and other collections, it, too, was eventually relocated to the NSSB. Since this move took place after the project team had completed its systematic review, however, this section describes the center as it existed prior to being relocated.

The Reports Collection contained both classified and unclassified reports published by LANL and numerous other entities, in paper and microfiche formats. The Reports Collection maintained its holdings in three principal collections: classified reports, unclassified reports, and unclassified microfiche. The project team's systematic review of the Reports Collection approached each of these three collections individually. Fig. 3-20 through Fig. 3-23 illustrates some of the stationary shelving, movable shelving units, and Lektriever units that were used in the Reports Collection.

As with the other systematic document search activities that began early in the project, initially logs were kept of everything reviewed in the Reports Collection, regardless of whether it contained relevant information. This practice of formally documenting every item that was reviewed was eventually found to be unnecessary, and was thus discontinued when document search activities resumed in February, 2005 following the security stand down. This change, plus that of dispositioning material by title, greatly improved the efficiency of the systematic review of the Reports Collection without compromising its effectiveness.

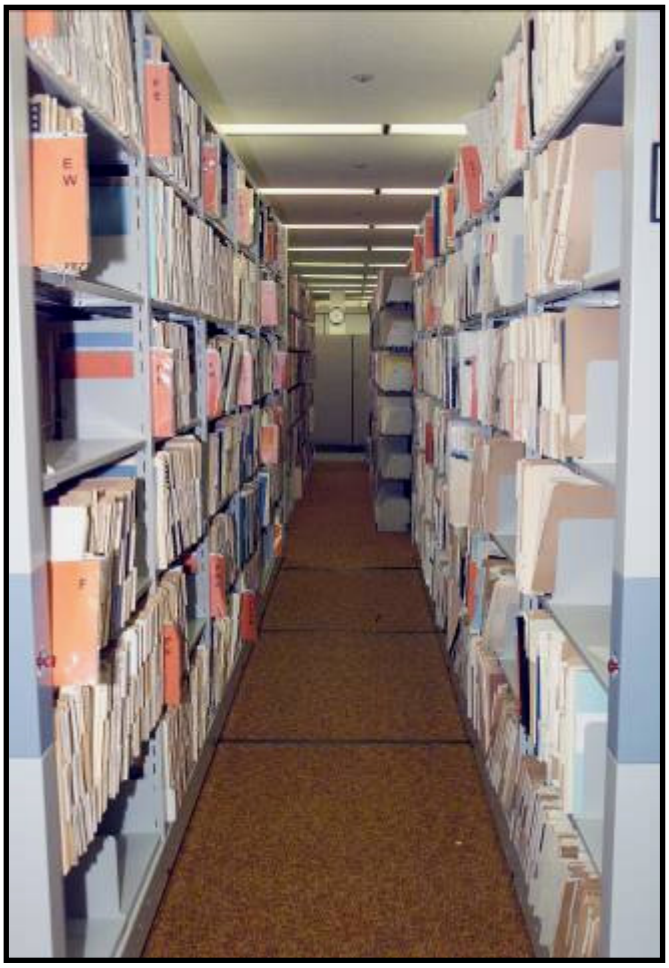


Fig. 3-20. Reports on stationary shelving in the LANL Reports Collection vault

Fig. 3-21. Reports on moveable shelving in the LANL Reports Collection vault

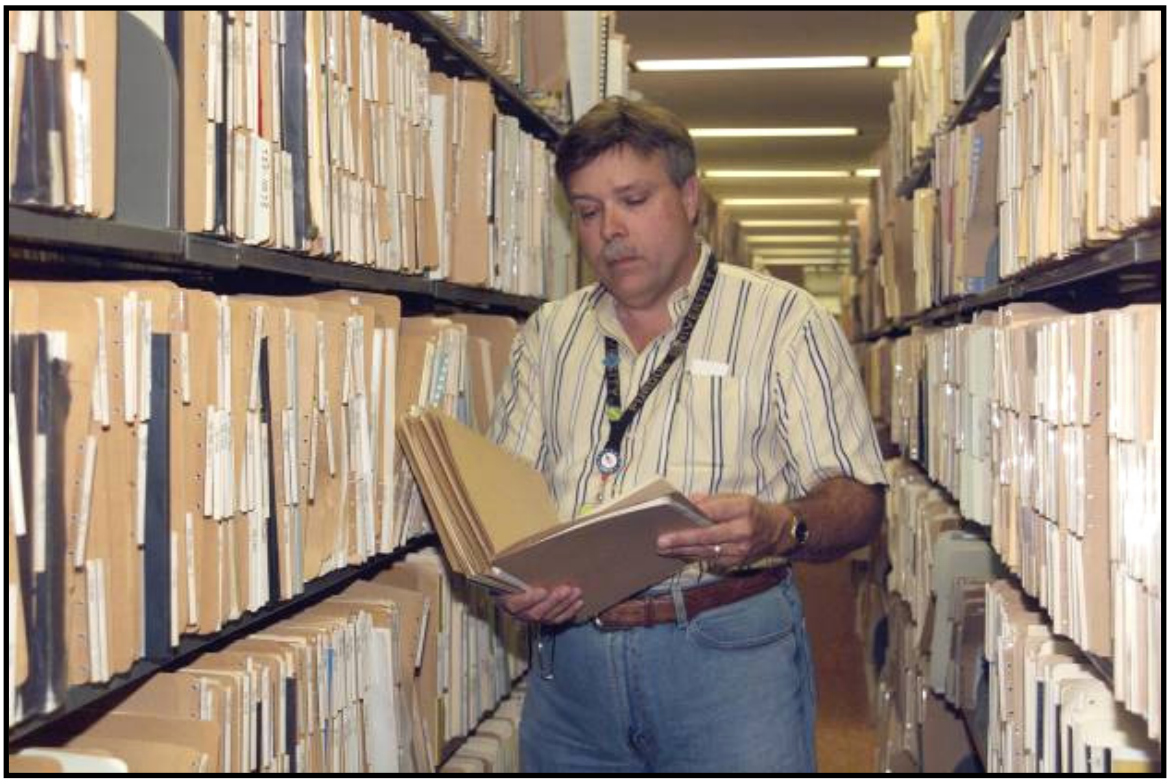


Fig. 3-22. Review of technical reports in the LANL Reports Collection

Fig. 3-23. Microfiche copies of reports are stored in "Lektriever" units such as this in the LANL Report Collection vault

Since there were no complete or reliable finding aides for the Reports Collection holdings, the systematic review of the Reports Collection was performed by reviewing documents shelf by shelf. The largely static nature of the Reports Collection holdings made this procedure effective.

Review of the Classified Reports Collection – The classified reports collection consisted of reports that were classified at the time of their publication. The reports were published by LANL and numerous other entities, including other weapons complex sites, military organizations, and contractors. The majority of the reports pertained to weapons program activities (testing in particular) and other large defense programs, such as Rover. The reports published by LANL included those in the LA-series and those generated by various groups such as SS (material accountability), W-division, X-division, etc. The reports were stored on collapsible shelving in alphabetical order.

The classified reports collection included approximately 3,000 classified report titles issued by LANL as LA- or LAMS- reports. Quantities are reported as titles rather than as individual documents since there can be multiple copies of a given report in the collection. In addition, the classified reports collection contained approximately 32,000 titles from organizations such as other weapons complex sites, other defense-related agencies, academic institutions, and private corporations that conducted research on behalf of DOE or its predecessor agencies.

To address the issue of excluded material, ultimately classified reports were reviewed by a LAHDRA analyst working in tandem with a reviewer authorized by LANL to pre-screen material for excluded information. This arrangement worked well, and the systematic review of the classified reports collection was completed in June, 2005. Additional ad hoc reviews of some of the holdings in the classified reports collection were subsequently performed to follow-up on information learned from the earlier reviews.

Review of the Unclassified Reports Collection – The unclassified reports collection was similar to the classified collection, but contained only unclassified documents. As such, the subject areas covered were more broad than those in the classified reports, and tended to yield more material of interest to the LAHDRA project.

The Reports Collection contained approximately 10,000 unclassified report titles issued by LANL as LA- or LAMS- reports. In addition, images of approximately 25,000 unclassified LA-, LA-MS-, LA-UR, and LA-PR reports were available as PDF files in the LANL electronic library catalog. Unclassified reports with limited distribution categories, such as those marked OUO (Official Use Only), were not available electronically, and had to be reviewed in the vault.

Prior to the heightening of security measures following the terrorist attacks of September 11, 2001, the unclassified "LA" reports were available to the public on LANL's web site. Subsequently, those files could only be accessed from a computer with a LANL IP address or by certain other government computer users. The project team reviewed 100% of the unclassified "LA" reports that were formerly available without restriction on the Internet. Most of these reports were reviewed using LANL computers at an office made available to the project team at TA-35.

In addition to those issued by LANL, there were approximately 90,000 unclassified reports in the Report Library vault issued by non-LANL entities, including:

- DOE sites other than LANL,
- academic institutions,
- private corporations that conducted research on behalf of DOE, and
- other defense-related agencies.

Systematic review of the hard copy holdings of the unclassified reports collection was completed in November, 2006.

Review of the Unclassified Microfiche Collection – Historically, LANL subscribed to multiple UC (University of California) distribution codes for DOE-related reports. When the Office of Scientific and Technical Information (OSTI) took over the distribution of DOE-related reports, it began distributing the reports on microfiche instead of paper. As a result, the LANL Reports Collection contained approximately 1.5 million documents on microfiche. In 1999 the LANL Research Library converted to an electronic subscription service, so documents were no longer added to the microfiche collection. Instead, library staff accessed reports via online databases (not hosted by LANL) upon request.

All of the microfiche reports were unclassified, but some were marked for limited distribution. Journals were not included in the microfiche collection because of copyright laws. Many of the reports in the microfiche collection were conference proceedings. The fiche cards were stored in Lektriever™ power filing units in alphabetical order (by document number). The documents in this collection included approximately 22,225 LA reports, according to the Library Catalog. Duplicates of these reports existed between the paper and microfiche collections, so the reports on microfiche did not need to be reviewed again if a paper copy of the same report had already been reviewed. Of the non-LANL agencies represented in the microfiche collection, the three largest (in terms of number of reports) were DOE Energy (~500,000 reports from 1969 to the present), Nuclear Science Abstracts (NSA; ~100,000 reports from 1949 through 1976), and NASA (~20,000 reports).

The Research Library subscribed to two electronic databases, DOE Energy and NSA, and, until recently, had also subscribed to the NASA electronic database. A search of the DOE Energy and NSA databases showed that LANL was the authoring institution for approximately 11,000 NSA reports and 53,000 DOE Energy reports, or about 10% of the titles in each database.

Like the other collections in the LANL Reports Library, there was no complete finding aide available to allow searching the microfiche collection. The project team and LANL staff members therefore performed a cataloging (mapping) of the numerous entities represented in the millions of pages of reports contained in the microfiche collection, resulting in an estimate of approximately 600,000 cards of microfiche in the six Lektrievers. The submitting organizations represented in these cards were differentiated into three broad categories to facilitate developing a search plan for this material. For each category of material, a fraction was reviewed for information relevant to the LAHDRA project. The categories of information and their associated review fractions are given in Table 3-3 below.

Table 3-3. Review fractions for categories of unclassified microfiche in the LANL Report Collection

Category	Description	Review Fraction
A	Reports from DOE or DOE sites, LANL-originated reports, and New Mexico-related documents.	100%
B	Reports from DOD, NASA, other U.S. Govt. organizations, U.S. businesses, or U.S. universities.	1%
C	Reports from foreign (non-U.S.) organizations.	None beyond that performed in the mapping process

The decision not to review the material from non-U.S. entities any further was based on the sampling of the documents in the microfiche collection intrinsic to the mapping process. Formal review of the microfiche collection was completed in March, 2006. All relevant material identified from the Lektriever collection was received from LANL and entered into the LAHDRA database. The majority of this material was Category 3 information (i.e., pertinent to sites other than LANL).

Review of the LANL Research Library – LANL's central research library, in general, did not serve as a central repository for records. It did, however, contain some public domain records, such as those associated with the "human radiation experiments" initiative and LANL's annual environmental summary reports. The project team searched these collections and retrieved a number of records from them. In particular, a number of Health Division records were obtained from the Research Library, as they were included among documents associated with DOE's human radiation experiments project.

The ES&H Records Center and Other ES&H Records

The initial systematic reviews of the holdings in the Environment, Safety, and Health (ES&H) Records Center were completed earlier in the LAHDRA project. More recently, the holdings of the ES&H Records Center were relocated to the NSSB and housed in the same area as the primary Records Center. After the documents were relocated, the project team completed follow-up review activities of those accessioned since the prior review activities were completed. In all, there were three systematic reviews of the holdings of the ES&H Records Center to ensure that material accessioned since the prior review was evaluated.

This summary of document review activities for the ES&H Records Center reflects group and organization names that were in use at the time review activities began. Since that time, LANL went through numerous organizational changes, making the group and organization designations below largely obsolete. The previous organizational designations have been retained, however, in order to preserve the summary of the review activities in sufficient detail.

Description of the ES&H Records Center – Prior to its relocation to the NSSB, the ES&H Records Center was located in Building 46 at TA-35. The center began operating in 1998. Its purpose was to receive records from the various ES&H Groups, catalogue and consolidate them, and eventually forward them to the LANL Records Center. Many of the records stored at the ES&H Records Center were recent (i.e., from the 1990s forward), but older records were found as well.

In Building TA-35-46, the records were stored in a combination of 25 rows of shelving and 9 file cabinets. The shelving units were used to store standard one cubic foot boxes. The file cabinets were used to store a combination of boxes and other items or containers. Often there would also be numerous boxes staged in various areas of the center that had not yet been accessioned. Some of these un-accessioned records would also be placed in the shelving units.

At the time, contents of records stored at the ES&H Records Center were described on CIC Form 170, the Records Transfer Request Form. This form defined a unique transfer record (TR) number for each set of records submitted to the center. The format of the TR numbers used for materials accessioned by the ES&H Records Center differed from those used by the primary Records Center. The ES&H format was TR-120-xxxx, where "xxxx" was a sequential number. The TR numbers were used to track records in a database maintained for that purpose. Hardcopies of the TR forms were kept in binders, with a different binder used for each group. Following its relocation to the NSSB, the holdings of the ES&H Records Center were stored on collapsible shelving units within the main Records Center.

Other ES&H Records – Some ES&H groups held records that had not yet been sent to the ES&H Records Center or the main Records Center. Group ESH-17 (Air Quality), for example, kept records in file drawers organized by year. They kept records for the three most recent years, and sent those for prior years to the ES&H Records Center. Group ESH-20 (Ecology) stored their records in files organized by topics such as Biology, Contaminate Monitoring, and Cultural Resources. In general, these types of record collections were considered to be active records rather than part of a formal collection. Table 3-4 shows the groups that existed within the ES&H Division when systematic review activities began, and whether they held records independent of the ES&H Records Center.

Table 3-4. Additional records held within ES&H Groups

ES&H Group	Additional Records?
ESH-1: Health Physics Operations	No
ESH-2: Occupational Medicine	No
ESH-3: Integrated Risk Analysis, Management and Communication	No
ESH-4: Health Physics Measurements	No
ESH-5: Industrial Hygiene and Safety	Yes
ESH-6: Nuclear Criticality Safety	Yes
ESH-7: Occurrence Investigation	Yes
ESH-10: Hazardous Materials Response	No
ESH-12: Radiation Protection Services	Yes
ESH-13: ES&H Training	Yes
ESH-14: Quality Management	No
ESH-17: Air Quality	Yes
ESH-18: Water Quality and Hydrology	Yes
ESH-19: Hazardous and Solid Waste	No
ESH-20: Ecology	Yes

Because these additional records were considered to be "active," a detailed review was not performed as part of the initial systematic review for the ES&H Records Center. Instead, the project team generated descriptions of these additional records to identify those to be reviewed in the future. These reviews were performed under the review of records held by the ENV Division, described later in this chapter. These reviews took place following a number of reorganizations and consolidations within LANL, so the groups described later in this report do not necessarily reflect those above.

Review of the ES&H Records Center – The bulk of the systematic review of the ES&H Records Center took place between January and October, 2000. Records were reviewed at their storage location.

Following review, records were marked using one of the two rubber stamps described earlier based on whether they contained any Category 1, 2, or 3 documents. A log entry was made identifying the material reviewed by its location and its TR number. The log entry included the document category assigned to the material, the analyst who performed the review, and the review date. A DSF was completed for any document identified as Category 1, 2, or 3.

On several occasions, records that had been reviewed were subsequently replaced with newly accessioned records. In general, these new records were also reviewed, meaning that several locations were reviewed two, and even three, times as new material displaced older material in the Center. Since the ES&H Records Center was an active staging area for records, a cutoff accession date of October 31, 2000 was established as a stopping point for the initial review. The rationale for choosing this date was the fact that all of the accessioned material in the Center had been reviewed by then, and the rate at which new material was being accessioned was too slow to justify a continuing effort. Instead, material accessioned after October, 2000 would be reviewed at some point in the future.

A total of 1,187 boxes were reviewed during the initial systematic review of the ES&H Records Center. Of these, 227 (19%) were found to contain relevant material. The majority of the relevant materials wre designated as Category 2, as they were primarily records from the 1990s that were already readily available in published reports. Examples include AIRNET (NESHAPS) data used in periodic reports required to document exposures to the public from LANL operations and airborne effluent data reported in annual environmental surveillance reports.

One of the most useful finds from the initial systematic review of the ES&H Records Center were two notebooks of working notes and document excerpts that contained data on LANL's historical, site-wide radionuclide releases (Andrews, ca. 1973). The first notebook (Volume 1 – Repos. No. 1733) contained data from 1948 to 1972. The second (Volume 2 – Repos. No. 1734) contained data from 1972 to 1996. These compilations had been assembled by LANL as an element of its response to a request from headquarters to assess its historical radionuclide releases.

In July, 2003 the ES&H Records Center was revisited to review material that had been accessioned since the initial systematic review. Copies of all Transfer Requests generated since October, 2000 [TR Numbers 120-186 (11/14/00) through 120-358 (6/20/2003)] were obtained, and the records descriptions were examined to identify any potentially relevant material. Ten boxes were selected for further review, but no additional relevant documents were identified. In early 2009, another follow-up review was performed for material accessioned by the ES&H Records Center since the previous review. This review

was carried out in the same manner as that conducted in July, 2003, and generated the same result: no additional relevant material was identified.

The Engineering Drawings Facility

In February, 2006 the project team began reviewing documents held by the LANL Engineering Drawings Facility at TA-63. This facility housed engineering drawings and associated documents (memos, letters, specifications, etc.) dating back to the 1940s. The documents, which were all on microfilm, included topics such as engineering studies and bases for facility modifications. Modifications were often performed to correct issues encountered after a facility began operating, such as ventilation problems. The documents in the TA-63 facility therefore included information on such problems and their impacts; they also included such information as radionuclide concentrations in soil in the vicinity of release points.

The project team's review of the TA-63 drawings facility was conducted in a focused, but still systematic, fashion. The goal was to obtain material to support the prioritization of radionuclide and chemical releases from the early LANL facilities. The initial searching, therefore, was for drawings pertinent to Original Technical Area buildings (especially D Building), Omega Site facilities and associated stacks, DP Site facilities and ventilation systems, and the Los Alamos town site.

The TA-63 facility maintained a database of their drawings inventory. The database included fields for TA Number, keywords, titles, etc. Drawings were searched by reviewing titles to identify those of interest. The selected drawings were then physically reviewed, and copies were requested of those deemed relevant to the LAHDRA project. The database was also used to search for drawings by TA Numbers, including residential areas, as these were designated as TA-0. Approximately 1,000 historical drawings were selected as relevant to the LAHDRA project, obtained from LANL, and scanned to make them available via DocSleuth.

The project team also completed systematic review of the TA-63 microfilm records. As for the drawings, their review was conducted in a focused, systematic fashion, emphasisizing documents related to the original Technical Area, Omega Site, DP Site, or the Los Alamos town site.

The TA-21 Library

The TA-21 library was a collection of material housed in a portable building at DP West. Its purpose was to be a resource for individuals involved in decommissioning activities there. The facility included binders of memoranda, remediation investigation reports, and drawings. Much of this material had already been collected by the project team from its review activities in the Records Center and elsewhere.

Nonetheless, a systematic review of this facility was completed, and some documents and drawings of interest were retrieved.

The Records Processing Facility

The Records Processing Facility (RPF) managed records of what was formerly the Environmental Restoration (ER) group at LANL. Most of the holdings of the LANL Records Processing Facility, located at the Pueblo School Complex, had been scanned to PDF files and were available through an electronic document management utility. Review of this material is discussed later in this report. In addition to these electronic records, the project team also reviewed some hardcopy records that existed at the RPF earlier in the project, as well as records that had recently been acquired and not yet scanned.

Division or Group Records and Electronic Databases

As the project team completed its systematic review activities for LANL's centralized records collections, it migrated its focus to records held within division or group offices. These were records that, for whatever reason, were maintained by their custodial organizations rather than one of the centralized records centers. These records included electronic databases. It was not the goal of the project team to review the records held by every LANL division or group; rather, the project team selected a subset of LANL's numerous divisions that it felt had the greatest potential for providing information of interest. In general, this selection process focused on divisions responsible for core Laboratory functions, eliminating those that served in only administrative capacities.

The initial focus of the review of division and group records was the Environmental Stewardship (ENV) Division (As before, the discussions in this section reflect the organization of LANL's divisions and groups that existed when records review activities took place. The division or group titles may not reflect the current organizational structure due to frequent reorganizations). The ENV Division consisted of a large number of groups, many of which held records of interest to the project team. Review of these records was therefore a substantial part of the team's activities once reviews at the centralized collections had largely drawn to an interim close. Review of records within the ENV Division is discussed later in this chapter.

Beyond the ENV Division, project team members also met with representatives of a number of other LANL divisions and groups to inquire about their activities and any records they held. The groups and divisions represented included:

- Associate Directorate for Security and Safeguards
- Chemistry

- Dynamic and Energetic Materials
- Earth and Environmental Science
- Environmental Protection
- Hydrodynamic Experiments
- Industrial Hygiene and Safety
- Materials Science and Technology
- Plutonium Manufacturing and Technology
- Radiation Protection
- Weapons Component Manufacturing
- Weapons Engineering Technology

Review activities that resulted from these discussions are described in the subsections that follow.

ENV Division Records

In May, 2006 the project team obtained a summary of records and databases generated by the groups and programs within the LANL Environmental Stewardship (ENV) Division. There were approximately 50 groups and programs listed, along with a number of electronic databases. The function of most of the groups and programs was to collect data needed to demonstrate compliance with state and federal regulations or those that were otherwise required by the Compliance Order on Consent in place between LANL and the NMED (At the time, the Consent Order was the principal driver of LANL's environmental remediation and surveillance programs). Numerous databases had been created within the ENV Division to store and manage the data collected by these groups and programs.

The project team met with numerous individuals representing various groups and programs within the ENV Division. Team members spoke with these individuals about the types of information collected and maintained by the groups and the programs they represented. These discussions were the basis for the team's approach to selecting which records to review within the ENV Division, and for prioritizing these reviews. The groups and programs represented in these discussions included:

- Ambient air sampling
- Cultural Resources
- Direct Penetrating Radiation network (ambient monitoring)
- Environmental surveillance
- Geographic Information Systems
- Meteorological monitoring and data
- NEPA, Environmental Assessment, and Environmental Impact Statement records
- NESHAP compliance (radioactive emissions)
- Non-radioactive regulated air emissions and air quality permits (Clean Air Act)
- NPDES, pesticides and sanitary waste

- RCRA permits and records
- Records Processing Facility (environmental restoration and related records)
- Sample Management Office (sampling and analysis files)
- Soil and biota monitoring program (including DARHT)
- Storm water data (Clean Water Act)
- TA-54 performance assessment
- TSCA, PCBs, solid waste, and underground storage tanks

The Domino and PRS Databases – Of the document collections and other information sources identified within the ENV Division, the largest, by far, was the Records Processing Facility's Domino database. The Domino database was an electronic storehouse for historical and current RPF records (i.e., environmental restoration files). These included environmental project case files, remediation management records, regulatory compliance records, and decontamination and decommissioning records. The records were stored as PDF files and managed using the IBM Lotus Domino application. Domino is actually a business collaboration package rather than a database application, but, as applied to management of the environmental restoration documents, it functioned similar to a database, and thus was referred to as such in the vernacular. The Domino application was accessed using a web-based front end that included provisions for searching.

Records in the Domino application were indexed using a unique identifier known as an ERID number. The system contained approximately 100,000 ERIDs, amounting to approximately 250,000 documents (a record could contain multiple documents). Systematic review of the Domino records was performed by looking at them sequentially by ERID number and reviewing those with titles that were either of interest or too ambiguous to allow a judgment. Documents deemed relevant to the LAHDRA project were printed, and a DSF was completed.

The RPF maintained another database called the Potential Release Sites (PRS) database. The PRS database contained documents related to historical activities at so-called "potential release sites" (i.e., solid waste management units or other areas of concern). This database contained far fewer records than the Domino database. Review was performed in the same manner as for the Domino database: a listing of titles was reviewed to select records of interest for examination. Few records were selected, but some information of interest was obtained.

Other ENV Division Records – Below are other records collection identified within the ENV Division that were reviewed by the project team.

NEPA Records: Records pertinent to compliance with the National Environmental Policy Act (NEPA) and associated environmental impact assessments were stored in boxes and file drawers at TA-59. These records included documents associated with LANL's environmental impact statements and environmental assessments for LANL projects. They also included projects that were not required to have any NEPA documentation beyond a Department Environmental Checklist (DEC), or an Action Declaration Memorandum (ADM) upon which category exclusion declarations were based.

MAQ Records: The LANL Meteorology and Air Quality (MAQ) group maintained air quality and related records at its offices in White Rock, NM pertaining to open burning activities, beryllium operations, and other laboratory activities involving hazardous air pollutants. In general, these were recent records, going back no more than five years. Nonetheless a number of relevant documents were identified and retrieved. The review of MAQ records also included meeting with LANL staff responsible for the RADAIR (radioactive air emissions), STACKS (stack parameters), and RMUS (radioactive material usage survey) databases to gain an understanding of the information these resources contained.

Meteorological Data: Project team members met with LANL staff responsible for acquiring and managing meteorological data. Data were gathered from meteorological towers at several locations across the LANL site and from local weather monitors. Several reports were obtained by the project team on subjects such as atmospheric dispersion modeling for the Los Alamos area, local precipitation data, and other local climatologic data.

Cultural Resources Group Reports: Project team members met with representatives from the LANL Cultural Resources group and reviewed a collection of their reports. Copies were subsequently requested of a number of these, as they included historical information about operations at LANL facilities.

The Litigation Support Database

In early 2000, the LAHDRA project team became aware of a number of small databases created for the Laboratory Counsel's office. These databases were known collectively as the Legal Counsel Litigation Support Database (LCLSD). Creation of the LCLSD began around 1990 with the scanning of numerous historical documents to image files. The documents selected were those potentially pertinent to the LANL Lab Counsel's activities. Many of the scanned documents were also subjected to Optical

Character Recognition (OCR), creating a searchable file of the text. The database contained approximately 500,000 pages of documents.

During the early stages of the LAHDRA project, team members made several attempts to gain access to the LCLSD. While the database itself was not made available, in 2003 the LAHDRA team received a hardcopy listing of the scanned documents available in five of the LCLSD's sub-databases. For each document the listing provided a document number, subject (title), author, addressee, copyee, date, status, and page count. The five sub-databases and the number of scanned documents available in each were:

H-Division	1,442 documents
Human Studies Project Team	4,767 documents
Central Records Management	11,198 documents
Others	10,395 documents
Records Processing Facility	47,922 documents
Total	75,724 documents

A description of the information contained in each of these five sub-databases is provided in the following section.

Sub-databases within the Litigation Support Database

H-Division: The H-Division sub-database of the LCLSD primarily included monthly (1943-1944, 1947-1964), quarterly (1965-1975, 1978-1990) and annual (1943, 1947, 1949-1953, 1957, 1987-1990) Health Division progress reports. It also contained progress reports from groups within the former Health Division, such as H-1, Radiological Monitoring (formerly H-6 and CMR-12), and H-4, Biological and Medical Research. Both of these groups were responsible for monitoring the use of radiological and non-radiological hazardous materials at LANL. Although the H-Division sub-database contained 1,442 documents, this number was a bit inflated, given that it typically included three versions of each H-Division progress report: a complete report, a version redacted for Privacy Act information, and an abstract of the complete report.

Human Studies Project Team: The 4,767 documents listed in the Human Studies Project Team (HSPT) sub-database consisted primarily of weekly status reports, fact sheets, press releases, news articles, procedures, phone logs, and other administrative documents generated during the HSPT's document review activities at LANL. The majority of these documents were generated between 1991 and 1995; however, there were also some historical documents from the 1940s, 1950s, and

1960s. There were also a large number of documents from the 1970s related to the Karen Silkwood case, pion radiotherapy studies, and the 1958 Cecil Kelley fatality.

Documents in the HSPT sub-database that were of interest to the LAHDRA project were the weekly bibliographies of documents released to the public, inventories of documents in LANL records collections, reports from the LANL autopsy tissue program, and H-Division monthly progress reports. The HSPT sub-database used a classification system for the H-Division reports that it contained. These classification categories were 001, Bayo Canyon activities; 002, DOD-related activities; 003, human tissue studies; 004, non-Bayo Canyon releases; 005, other DOE contractor (human studies); 006, tracer studies (plutonium, uranium, radioiodine, tritium, radium, other); 007, history/general; 008, atmospheric testing programs; and 009, pion radiotherapy.

Central Records Management: The 11,198 documents in the Central Records Management sub-database covered the years 1943 to 1965. These documents included:

- Monthly hazard and accident reports for month/year (1946-1954)
- Weekly health test data (1950-1956)
- Neutron exposure reports (1946-1958)
- Personnel exposure reports (1957-1958)
- Monthly and weekly reports (1951-1958)
- Monitoring results (1945-1957)
- Minutes from weekly Section Head meetings (1945-1955)
- Air Counts, pencil and ink originals (1950-1962)
- Hand, head, shoe and nose counts (1944-1956)
- Urinalysis/urine counts (1944-1957)
- Film badge exposures (1957-1958)
- Protective Equipment- respirators, clothing (1947-1962)
- Safety meetings (1961-1962)
- Experimental shots at TA-33 (1948-1955)
- Tritium exposures at TA-33
- SL-1 accident
- DP Site explosion (1-14-1947)
- Pajarito accident (1-8-1953)

Others: The 10,395 “Other” documents were primarily administrative records covering the period from 1943 to 1989. Examples of these records are:

- Contracts and contract modifications
- Reimbursement authorizations
- Personnel policies regarding overtime, moving expenses, employee benefits
- Personnel administrative panel meetings

- Organization charts (1945-1989)
- Telephone directories (1944-1989)
- The Atom (1964-1975)
- Annual reports to Congress of the AEC (1948-1973)

However, several other types of documents were also included, such as:

- Annual environmental monitoring reports (1970-1992)
- H-Division progress reports (1943-1980)
- RFI work plans for operable units (1989-1990)
- Glenn Neely Notes
- Dept. of Labor log and summary of occupational injuries and illnesses (1989-1992)
- Occurrence reports
- Newspaper articles

Records Processing Facility: As previously discussed, RPF documents were records from the Environmental Restoration program at LANL. The 47,922 documents in the LCLSD sub-database were also part of the Domino database discussed earlier in this chapter. The smaller number of documents reflects the fact the LCLSD sub-database only contained a subset of the total number of environmental restoration documents. The project team's review of the RPF sub-database predated its review of the Domino collection.

Review of the Litigation Support Database

Project team analysts reviewed the hardcopy listings of the document titles in each sub-database and selected documents for review. Ultimately, only 5% of the documents available in the five sub-databases were selected. The remainder were either clearly non-relevant or had already been captured by the project team from other collections. A breakdown of the number of documents selected from each sub-database is shown below.

H-Division	86 documents
Human Studies Project Team	155 documents
Central Records Management	1,706 documents
Others	764 documents
Records Processing Facility	1,102 documents
Total	3,813 documents

Project team analysts reviewed the selected documents electronically using commercial information retrieval and viewing software provided by LANL. The software allowed analysts to review the documents in a given sub-database one at a time, establish bookmarks where they left off, or jump to specific documents. Relevant documents were printed using a dedicated printer and attached to the

corresponding DSF. Analysts also checked the LAHDRA project database to determine if a selected document had already been retrieved.

Systematic review of the scanned documents in the five LCLSD sub-databases began in May, 2005, and was completed in September, 2005. Approximately 400 documents (10% of the 3,813 selected for review) were selected and retrieved.

Weapons Engineering and Manufacturing and Weapons Physics Records

Systematic records reviews completed by the project team earlier in the project included a review of records held by the Weapons Engineering and Manufacturing (WEM) and Weapons Physics (WP) divisions. The nature of these records, though, combined with the information security restrictions imposed on project team analysts at that time, meant only a limited review was possible. The reviews were conducted in accordance with a Special Security Plan that was issued in June, 2001.

The reviews focused on the contents of the WEM and WP vault-type room (VTR) located in the Administration Building at TA-3. Most of the documents held by these two divisions were classified, and contained nuclear weapon design and testing information. All of the classified documents reviewed in the VTR were published after 1962; the Special Security Plan in place at that time meant, then, that the reviews had to be performed on a restricted-access basis. In other words, project team analysts had to review the documents by title alone, and were prohibited from reviewing its contents.

At the time of the review, the WEM and WP division records consisted of approximately 18,876 classified documents and 1126 classified photographs. There were also classified video media of various formats (e.g., VHS). The project team was not allowed to review the videos. Based on their titles, two documents were identified by the project team as potentially relevant. An appeal was made to DOE for a team member to be able to review the contents of these documents to determine of they were indeed relevant, but it was denied.

Thirty-six classified safes were also reviewed for potentially relevant information. The safes contained 7,056 classified documents. Review of these documents (by title alone) did not identify any items relevant to LAHDRA.

LANSCE Records

Earlier in the project, team members performed a systematic review of records held at the Los Alamos Neutron Science Center (LANSCE), located within TA-53. The reviews focused on files within the Main Administration Building (TA-53-1) and the Radiological Air Monitoring Records Archive located in

Sector R, Building 3, Room 3R-4 (TA-53-3). Approximately 10,000 documents were reviewed in the Main Administration Building. Of these, approximately 2,500 were identified as potentially relevant and underwent detailed review. Ultimately, 36 of these documents were retrieved; they included shift supervisor logbooks that contained daily beam current and beam-hour data from as far back as 1971.

Forty-five boxes of documents (3,375 documents) located at the Radiological Air Monitoring Records Archive (Building 3R) were reviewed. Approximately 20% of these were identified as duplicates. The documents contained detailed information on radiological monitoring techniques and results from 1971 to the present. Most of them pertained to airborne releases from LANSCE. Ninety-seven documents were retrieved by the project team.

Beryllium-Related Records

The project team reviewed records held by the Industrial Hygiene and Safety (IH&S) group at TA-59. The focus of this review was older records from the former H-5 (industrial hygiene) group. H-5 was responsible for monitoring beryllium and other hazardous materials used in LANL operations. A number of relevant documents were identified

On several occasions, project team members met with the LANL beryllium program coordinator to discuss beryllium operations, releases, and records. This individual provided the project team with a number of useful reports pertaining to beryllium operations and releases at LANL.

On recommendation from other LANL staff members, the project team reviewed reference material used in preparing the environmental impact statement for the DARHT facility. Several documents were retrieved, addressing subjects including releases of aerosolized uranium and beryllium from dynamic experiments and concentrations of these materials in local soils.

Hydrodynamic Testing Records

The project team visited a classified vault in TA-22 that contained records from hydrodynamic testing activities conducted by several LANL groups and divisions. At the time, the vault contained approximately 10 rows of collapsible shelving, plus a number of flat-file cabinets used to store drawings and radiographs. The hardcopy records stored on the collapsible shelves included chronological files (sequential memos and reports by date), correspondence files, and shot folders. The shot folders included shot summary reports and other detailed information. Sometimes information on materials included in a shot were given in detail (e.g., the mass of a specific material), and, in other cases, only part numbers were given (along with their mass).

It was not the goal of the project team to perform a systematic review of this material; rather, the intent was to conduct a preliminary review of the types of information contained in the shot records and prepare a summary for future reference. Nonetheless, one document was selected for retrieval by the project team during its visit. It was redacted as required to make it unclassified, and released. Several other documents pertaining to materials expended in shot activities in the early 1990s were noted(By this time, security restrictions had been relaxed such that appropriately cleared project team members were allowed to access the records in the TA-22 vault as long as they did not contain any Sigma 14 or Sigma 15 information).

On several occasions, project team members met with representatives from the LANL Hydrodynamic Experiments (HX) Division to discuss their activities and records. These discussions led to the compilation of a box documents describing materials expended in shot activities and its subsequent receipt at the LANL Records Center, where it was reviewed by the project team. A number of useful documents, akin to some of those seen in the TA-22 vault, were identified and requested. These documents were unclassified, though several of them had to remain OUO status given their content.

Other Sources of Information

Project team members searched the photographic records of the Los Alamos Historical Society and obtained prints of photographs and maps of interest. More than 50 photographs were obtained, primarily aerial views of LANL facilities and surrounding areas from the 1940s and 1950s. The project team also obtained a title listing of photographic records held by the LANL Environmental Stewardship Division. Prints were obtained of numerous photographs from the early years of LANL operations at TA-1, TA-2, and TA-21. Numerous other photographs were also obtained through records review activities at LANL. The project team also obtained several videotape records from the Broadcast Media Gallery of the LANL Public Affairs Office.

As the LAHDRA project progressed, the CDC also supported and benefited from a series of interviews conducted by Peter Malmgren as part of his "Los Alamos Revisited" oral history project. Trained and experienced in anthropology and related fields, Mr. Malmgren was involved in several oral history projects in New Mexico over a span of many years. In his "Los Alamos Revisited" project, the 30-year Chimayo, NM resident set out to offer a special perspective on the lives and concerns of retired LANL workers. During the December, 2000 to March, 2003 period that the CDC supported his project, Mr. Malmgren conducted over 100 interviews. Interviews numbered 1 thru 116 (the number 76 was skipped) are summarized briefly, with full names not identified, in Repos. No. 4081 of the LAHDRA document collection (Malmgren, 2003). The interviews cover a very wide spectrum of jobs and life experiences of

people who worked at LANL and/or who lived in the general area. Detailed transcripts were produced by Mr. Malmgren, and the interviews were audio taped.

Interviews with Past and Current LANL Staff or Other Individuals

Interviews of current and retired LANL workers and other individuals were conducted by the LAHDRA team to assist in identifying and describing operations possibly associated with off-site releases, identifying relevant record collections, and developing an understanding of historical operations. Workers sometimes helped the document analysts assemble the "big picture" with regard to site operations. Interviewees also identified additional interview candidates with knowledge about specific subject areas, assisted with interpreting information from documents or other interviews, and describing record-keeping practices of years gone by.

Interview candidates were identified from author or distribution lists on key documents, from division rosters or progress reports, or from other interviews. While interviews were typically conducted with individuals, group interviews allowed participants to jog each others memories, yielding more information than may otherwise have been provided. All interviews were voluntary, and interviewees had the option to remain anonymous. In these cases, names were excluded from our records. In some cases, people who held security clearances in the past received special authorization to speak freely during an interview, provided it was conducted in an appropriate facility and according to all regulations and guidelines related to handling potentially sensitive content.

Summaries of interviews conducted by the project team are included in the project's information database. The database also includes transcripts and summaries of interviews with relevant LANL staff that were performed by LANL. These records were obtained from the project team's systematic search activities and from the Archives in particular.

Some of the individuals who were interviewed by the LAHDRA team included:

- Scott Hughes: graduate student doing research on the evolution of the ES&H program at LANL.
- J.W. Nyhan: LANL staff member re: stack emissions from DP West.
- Jim McInroy: LANL staff member re: human tissue analysis program.
- John Miglio: LANL analytical chemist.
- Jim Lawrence: LANL health physicist.
- Bill Moss: LANL staff member (health physics and industrial hygiene)
- Jay Wechsler: LANL staff member (radionuclides in soils)
- Ron Stafford: LANL staff member re: plutonium handling and releases.

- Scott Miller: LANL staff member (monitoring for airborne releases)
- Gary Whitney: LANL beryllium program coordinator
- Tom Newton: LANL chemist (retired, worked in D Building starting in 1949, then moved to CMR Building)
- Helen Cowan: Former chemist at the Manhattan Project's "Met Lab" in D Building at during World War II, and later in the CMR Building.

D Building Roundtable Discussion

LAHDRA team members worked with LANL personnel to set up a roundtable meeting with current and former LANL workers who were reported to have knowledge of operations and activities at D Building. D Building, part of the original Technical Area, was LANL's original plutonium processing facility. The meeting was held on July 25, 2006 at LANL to coincide with key project team members who were already in Los Alamos for a public meeting the following day. Attendance was limited to individuals with the required level of security clearance so that classified information could be discussed freely. The meeting was videotaped, however, and an unclassified version has been made available to the public.

Meeting attendees included:

- Charles D. Blackwell, General Monitoring Section, H-1, retired
- Carl W. Buckland, Leader, General Monitoring Section, H-1, retired
- W. Clarence Courtwright, explosives safety engineer 1955-1991, retired
- Raymond Garde, LANL, retired
- Donald R. Gibbons, LANL, retired
- Joe Vigil, LANL, retired
- Jack Buddenbaum, LAHDRA team member
- Bob Burns, LAHDRA team member
- Joe Shonka, LAHDRA team member
- Tom Widner, LAHDRA Project Director

Plutonium release estimates were not located for D Building, so the project team strived to learn as much as possible about the processing performed there. The goal was to determine methods for estimating how much plutonium could have been released. At the roundtable meeting, LAHDRA team members described what they had learned about D Building and the activities there. Attendees were asked if they could address specific questions that remained, such as details of key steps in early plutonium processing, airborne contamination, ventilation system and filter design, , and environmental contamination indicators. Unfortunately, though, the participants knew very little about D Building, but the project team did learn some useful information about other historic LANL operations.

Summary Statistics

Over the course of the LAHDRA project, team members reviewed millions of pages of information, resulting in the retrieval of approximately 264,000 pages of material relevant to the estimation of offsite releases of chemical or radionuclides from LANL or their associated health effects. This information is summarized in the 8,372 records that make up the project's information database.

Table 3-5 through Table 3-7 below show the breakdown of documents retrieved by the LAHDRA project team by document category, by original document location, and by decade of publication. It should be emphasized these statistics reflect the documents identified by the project team as relevant to the goals of the LAHDRA project during its review activities. By no means do these statistics reflect the overall distribution of documents at LANL, especially where publication dates are concerned.

Table 3-5. Breakdown of LAHDRA documents by assigned category

Document Category	Fraction
Category 1: information directly applicable to estimation of offsite releases or health effects from LANL operations within New Mexico	44%
Category 2: supporting or confirming information useful for estimating offsite releases or health effects from LANL operations within New Mexico	46%
Category 3: information relevant to estimating offsite releases or health effects for other DOE or predecessor agency sites	10%

Table 3-6. Breakdown of LAHDRA documents by location of origin

Document Location	Fraction
LANL Records Center	37%
LANL Reports Collection	19%
LANL Archives	13%
Domino Database	10%
LANL Research Library	5%
Litigation Support Database	4%
ES&H Records Center	3%
Engineering Drawings Facility	2%
All other locations	6%

Table 3-7. Breakdown of LAHDRA documents by publication date

Decade of Publication	Fraction
1940s	14%
1950s	16%
1960s	17%
1970s	20%
1980s	14%
1990s	16%
2000s	2%
Unknown	0.1%

References

Andrews LL. Los Alamos National Laboratory site releases up to 1972. Los Alamos Scientific Laboratory. ca. 1973.

Malmgren P. Brief Summaries of 115 Interviews Performed under the "Los Alamos Revisited" Oral History Project 2000-2003. 2003.

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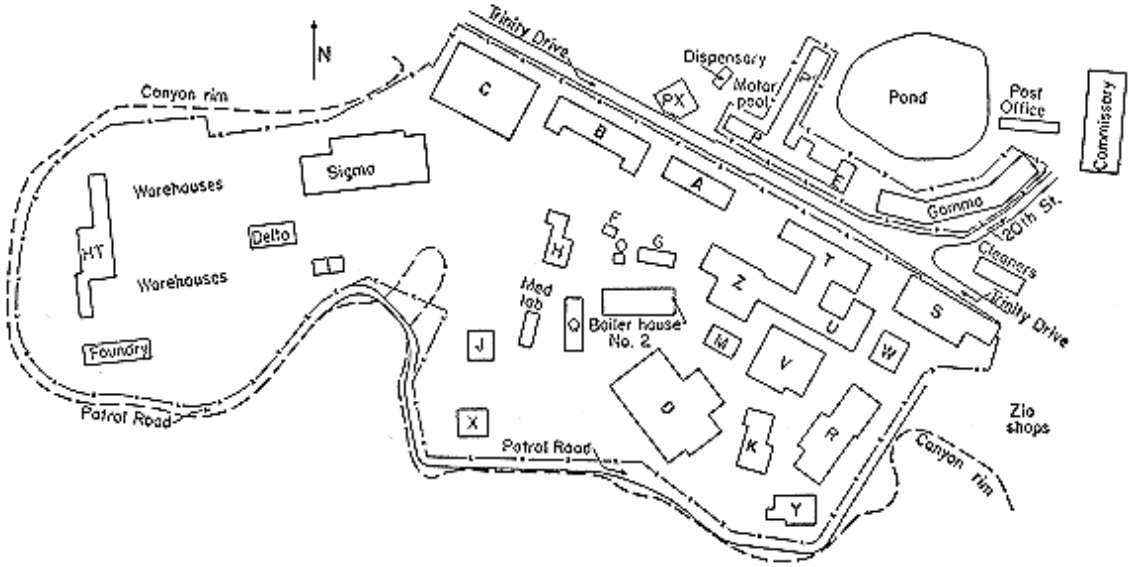
Chapter 4: Plutonium Processing at LANL

One of LANL's important early roles was to process the newly created and largely unknown material called plutonium (Hammel, 1998). The assignments taken on by LANL scientists in the mid-1940s were to:

- Perform the final purification of plutonium received at LANL,
- Reduce the plutonium to its metallic state,
- Determine the metal's relevant physical and metallurgical properties, and
- Develop the necessary weapon component fabrication technologies.

Los Alamos was the first site in the world to receive quantities of plutonium large enough to manufacture weapon components. Initial plutonium processing was performed in the Original Technical Area, which was located near Ashley Pond, and later became known as Technical Area 1 (TA-1) (see Fig. 4-1).



Key to Selected Buildings:

C- Shops
D- Plutonium Plant
E- Theoretical Division Offices
G- Graphite Fabrication
J- Research Laboratories
Q- Medical Offices
R- Laboratories
S- Stockroom
Med Lab = Medical Laboratory
U- Chemistry and Physics Labs
V- Shops
W- Van de Graaff Machines
X- Cyclotron
Y- Cryogenics Laboratory
Z- Cockcroft-Walton Generator
Gamma- Research for M Division
Sigma- Metals, Plastics, Ceramic Fabrication

Fig. 4-1. Map of the Original Technical Area (later called TA-1)

Early Plutonium Processing at D-Building

The initial plutonium handling and processing that took place at the original technical areas involved the following main facilities:

- D-Building- housed plutonium chemistry, metallurgy, and processing
- D-2 Building- housed contaminated laundry and glassware decontamination
- D-5 Sigma Vault- storage facility for ^{239}Pu and ^{235}U
- ML Building- Housed the Medical laboratory, site of human uptake and excretion
- studies by H-4 and H-5 groups and urine assay

D-Building (see Fig. 4-2) in LANL's Original Technical Area was the first site in the world in which plutonium was handled in visible quantities, purified, converted to metal, and used to fabricate atomic weapon parts. Because plutonium was a newly discovered element available only in milligram quantities, there was a great deal of pressure on scientists to perform the necessary metallurgical experiments as quickly as possible once gram-scale quantities of plutonium became available. At the time, impurities were of great concern, because α-particles are emitted from plutonium at a rate that is over 1,000 times greater than that of uranium. Upon colliding with light-element impurities, these α-particles release neutrons, greatly increasing the chance of a premature fission reaction occurring before much of the plutonium reaches a super-critical state. A premature ignition, known as a "fizzle," would greatly diminish the explosive power of the weapon.

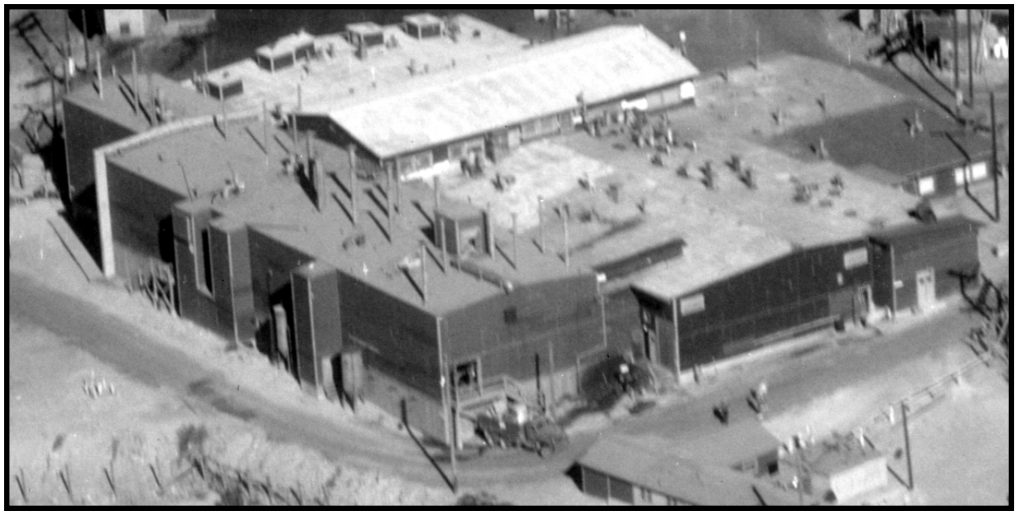


Fig. 4-2. D-Building in the original Technical Area on December 4, 1946 (looking north). *Photo courtesy Los Alamos Historical Society (from LAHM-P1990-40-1-3029).*

D-Building was constructed as an answer to this impurity problem in December, 1943. To mitigate light-element dust from settling onto experimental surfaces, D-Building was built with a state-of-the-art air conditioning and ventilation system that provided laboratory conditions that were as dust-free and clean as possible. The building's air intakes were filtered, but its exhaust vents were not. Starting in late 1943, scientists and engineers in D-Building used equipment and procedures considered extremely crude by modern-day standards to process plutonium, a new and largely unknown element, under demanding schedules and extreme wartime pressures. Progress reports indicate that D-Building and its roof became highly contaminated, and about 85 rooftop vents released contaminated air without monitoring, and, for the most part, with no filtration. A former LANL plutonium worker wrote that "during the War years, partly because of ignorance and partly because of the stress of wartime conditions, operations with plutonium in D-Building were conducted with greater laxity than has ever been tolerated since," and that "D-Building was known to be hotter than a firecracker" (Coffinberry, 1961). There are no records or LANL estimates of airborne plutonium releases from D- Building, which ceased main plutonium production functions when the DP West site became operational in late 1945, but remained active until around 1953.

Flow of Plutonium Operations within D Building

Operations within D Building can be considered a chemical process; the key objective wasto convert plutonium nitrate into the highly purified metallic hemispheres used in the Trinity and Nagasaki devices. While many other supporting projects were conducted within D-Building, including uranium chemistry and metallurgy, tamper and polonium initiator design, and various refractory materials development, this report focuses specifically on the numerous stages of plutonium processing. These stages are represented generally by the flow diagram shown in Fig. 4-3, which most accurately represents plutonium processing from about December, 1944, until D-Building was decommissioned in September, 1945. These production-scale processes, in operation for only about nine months, were refined from many months of prior chemical and metallurgical research starting in December ,1943 when construction of D-Building was completed. It is most likely, however, that the vast majority of plutonium contamination was a direct result of these production-scale operations, as the first few milligrams of plutonium did not arrive on site until January, 1944, and gram quantities did not arrive until March, 1944 (Hammel 1998). Moreover, by late April, 1945, D-Building had produced only about 1 kg of plutonium (see Fig. 4-4), yet would receive about 26 kg of additional plutonium from the Hanford site in Washington (Site W) by the end of August, 1945, as shown in Fig. 4-5 (Site Y, 1945). Because of this trend, this report focuses mainly on the production-scale processes.

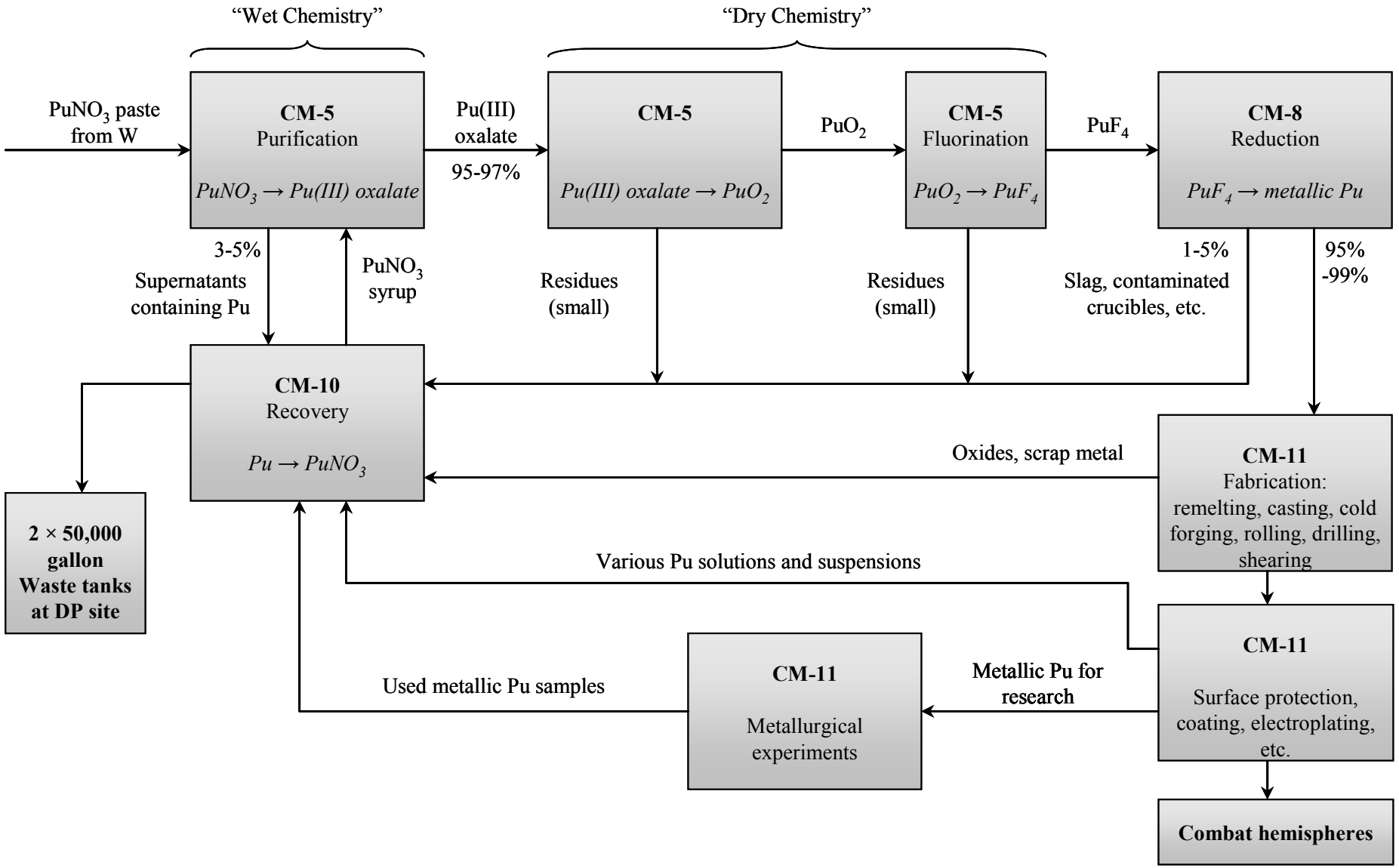


Fig. 4-3. Flow chart of plutonium operations in D-Building

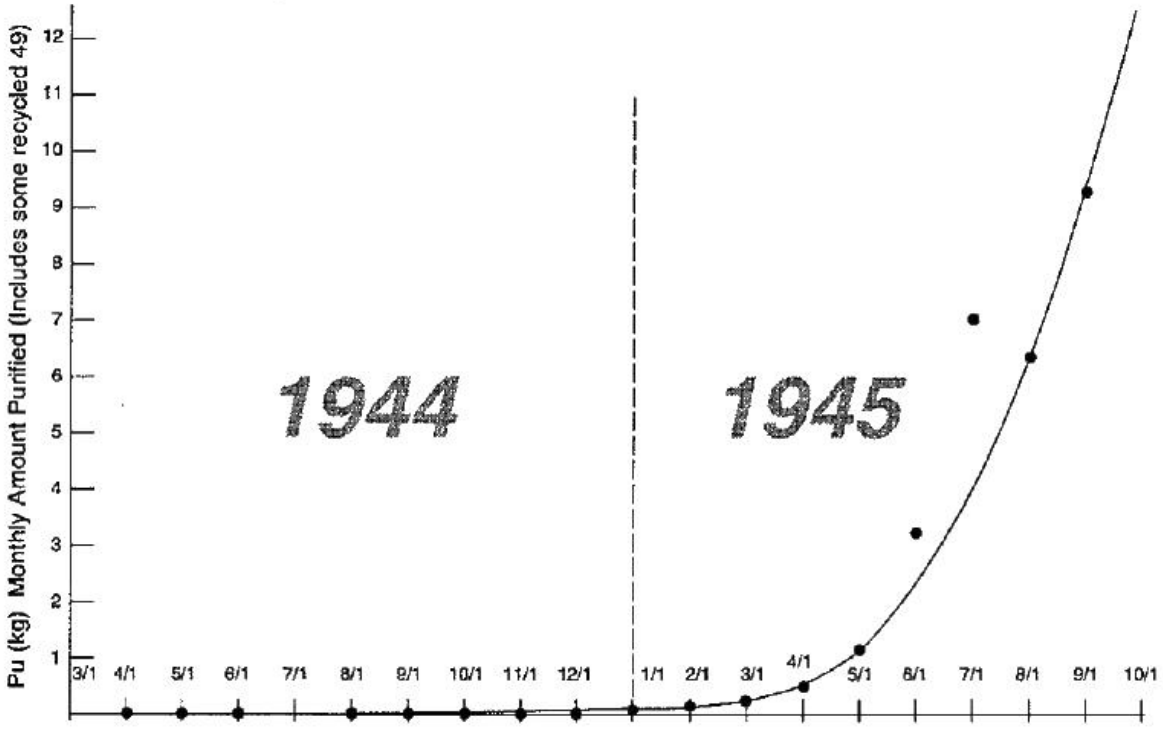


Fig. 4-4. Monthly amounts of plutonium produced from plutonium nitrate in D-Building. This graph is not cumulative; by September 1, 1945, purification operations were producing just over 9 kg of purified plutonium per month, roughly ten times what the rate had been on April 1, 1945 (Hammel 1998).

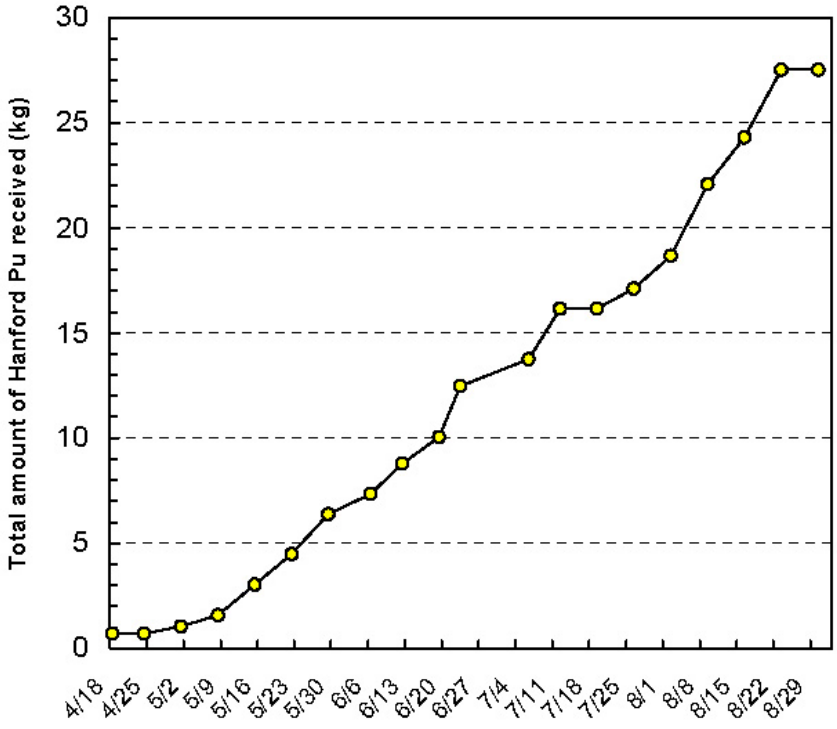


Fig. 4-5. Cumulative amounts of plutonium received from Hanford in 1945 (LANL (Site Y) 1945)

The bulk of plutonium arrived at D-Building in the form of relatively impure plutonium nitrate manufactured at the Hanford site. Fig. 4-6 shows one of the shipping "bombs" that were used to transport the material known as "49" or "product." A relatively small amount of the nitrate also arrived from the Clinton pile at Oak Ride, TN (Site X), though this material was used mainly for research purposes. As shown in Fig. 4-3, these nitrates were first converted into plutonium (III) oxalate by wet chemical techniques. This oxalate slurry was then underwent dry chemistry, or dry conversion, processes, whereby the oxalate was first thermally converted into plutonium oxide (PuO_2), and then fluorinated using a mixture of hydrogen fluoride (HF) and oxygen to form plutonium tetrafluoride (PuF_4). This plutonium halide was then reduced in the presence of a more electropositive metal, such as calcium, resulting in the formation of plutonium metal. The metal was then remelted and fabricated into a variety of shapes for metallurgical experiments and coated to protect the surface from oxidation. After each metallurgical experiment, the plutonium specimen was returned to the recovery group, converted back to plutonium nitrate, and sent to the purification group, who repurified, re-reduced, remelted, recast, and refabricated it. In this way, a very large amount of data was collected using the relatively small amounts of plutonium available at the time. A more detailed description of plutonium processing in D-Building prepared by the LAHDRA team is available elsewhere (Knutsen and Widner, 2007).

By August 31, 1944, J. Robert Oppenheimer stated in a letter that a total of only 51 g of plutonium had been received at LANL (Site Y). Remarkably, Oppenheimer noted that this material had been used in "approximately 2500 separate experiments," and "the overall loss per experiment has been about one per cent" (Hammel, 1998). An open hood that was used in D-Building for production-scale purification is shown in Fig. 4-7. The associated apparatus, most of which was made of glass, is depicted in Fig. 4-8 (Wahl, 1946). Irradiation of glassware caused it to become brittle, and the ether used in the processing was a recognized fire hazard. A furnace used for fluorination and oxidation reactions is shown in Fig. **4-9**. The manual transfer of dry powders from one step to the next in platinum "boats" was problematic, and led to some dispersal of material in the building. Stationary "bomb" reductions of plutonium tetrafluoride to plutonium metal were conducted in induction furnaces like the one shown in Fig. 4-10, and cylinders of plutonium metal were pressed into hemispheres using heated presses like the one shown in Fig. 4-11.

Between each stage in the process, plutonium compounds were stored in vaults and monitored by the Quantity Control group to prevent critical masses of plutonium from accumulating. Fig. 4-12 documents the processing of plutonium for four weapon cores in D-Building during 1945: one for the Trinity test, the first combat bomb (used in Nagasaki), a second combat bomb (not needed in Japan), and the first "composite" core that used active material in addition to plutonium (Wahl, 1947).

Fig. 4-6. Plutonium was received from Hanford in 80 g and 160 g batches in "shipping bombs" (right) as a slurry of plutonium nitrate. Shipping bombs were transported in protective cases shown on the left. *(Photo IM-9:1831 courtesy of LANL)*

Fig. 4-7. Production-scale purification was conducted in hoods that could be flooded with carbon dioxide in the event of an ether fire. *(Photo IM-9: 1829 courtesy of LANL)*

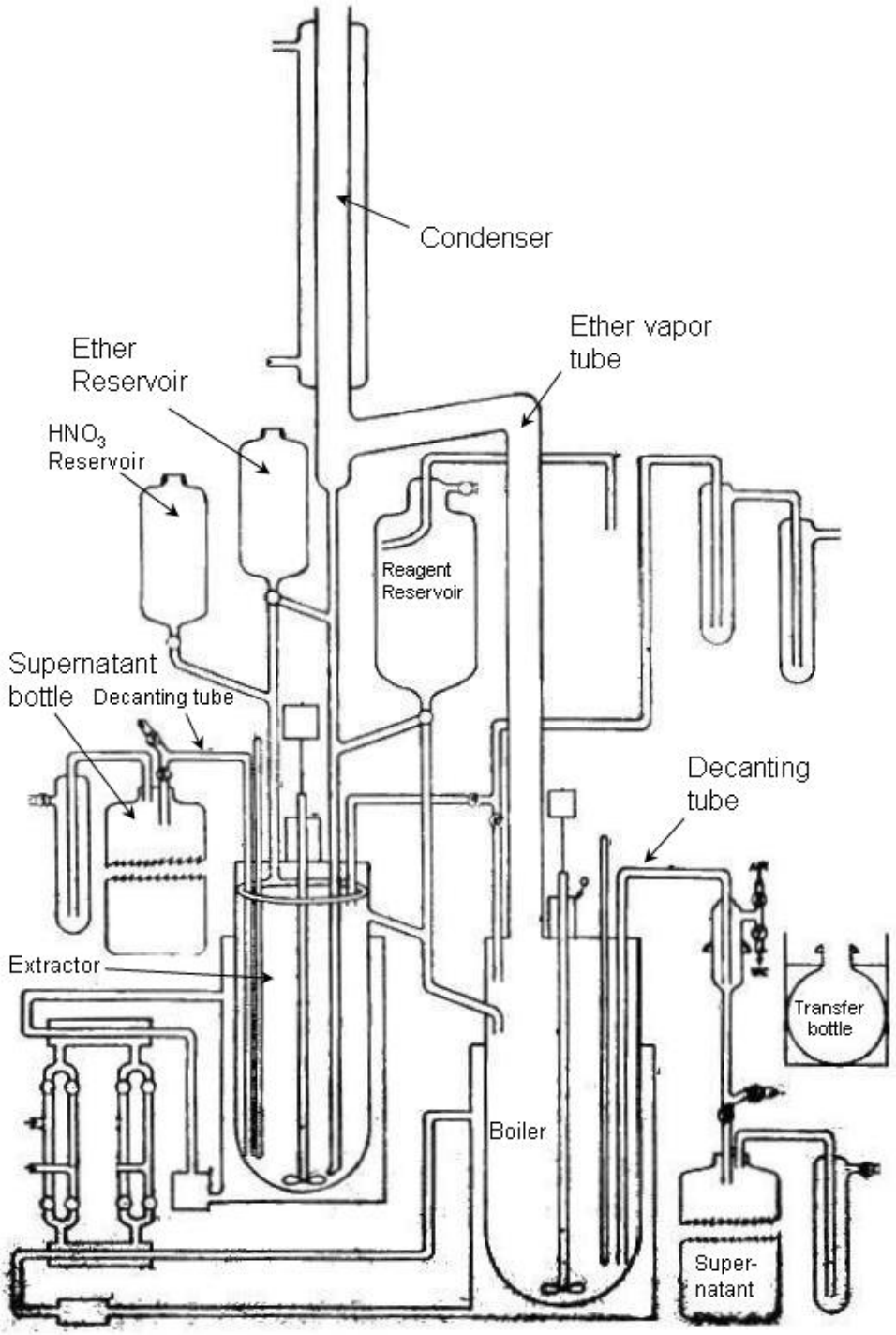


Fig. 4-8. Production-scale (160 g) purification apparatus (from Wahl 1946).

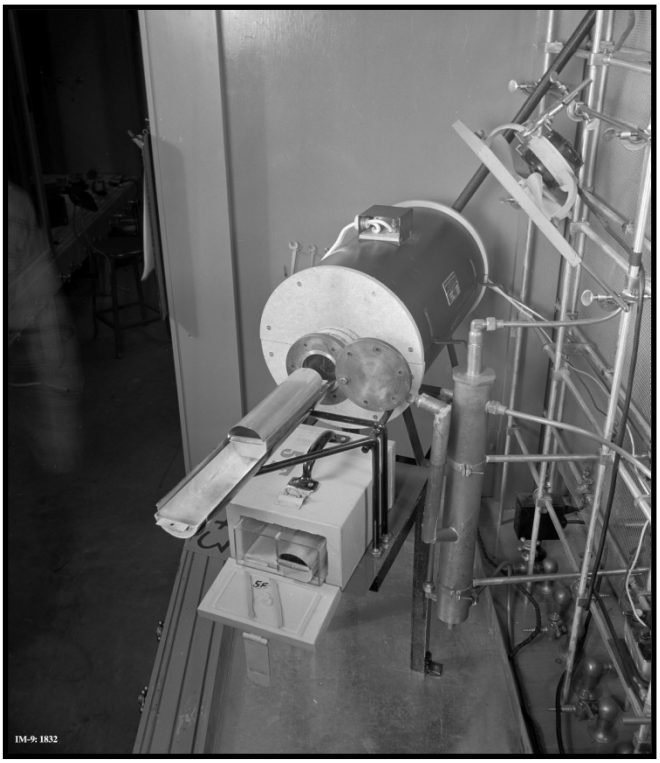


Fig. 4-9. A furnace that was used for fluorination and oxidation reactions *(Photo IM-9: 1832 courtesy of LANL)*

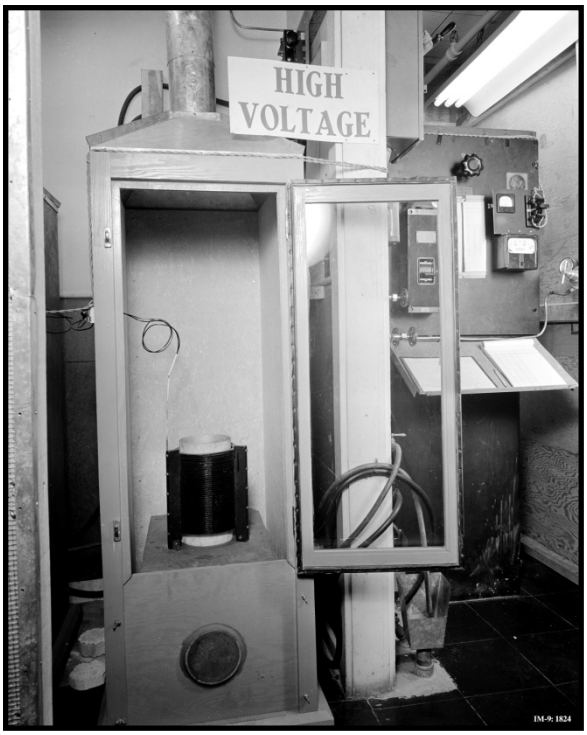


Fig. 4-10. This induction furnace powered by a 20 kW high frequency converter inside a fume hood was used to fire large-scale bomb reductions *(Photo IM-9:1824 courtesy of LANL)*

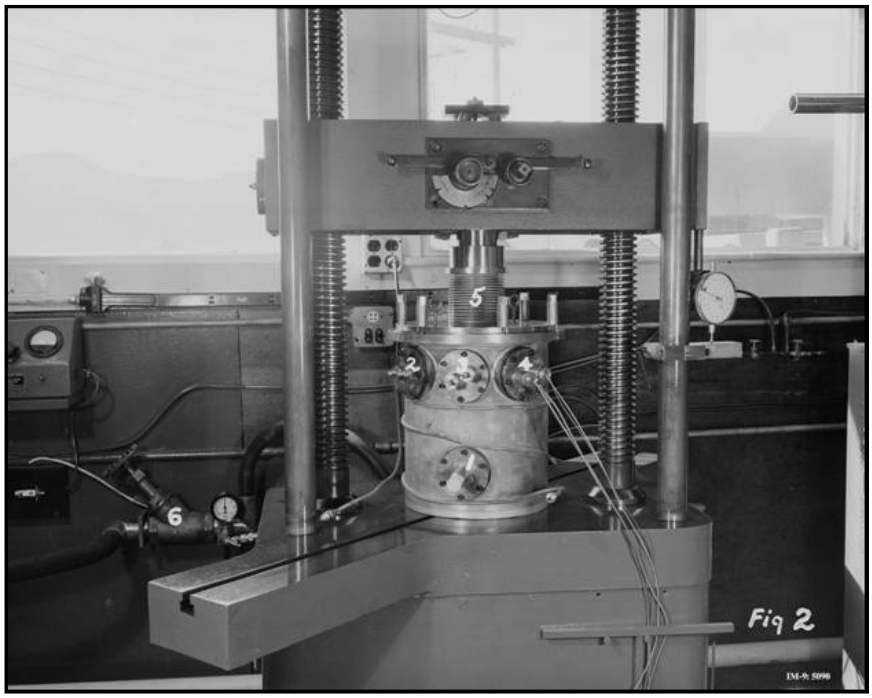


Fig. 4-11. Evacuated hot presses like this were used to form hemispheres of plutonium *(Photo IM-9:5090 courtesy of LANL)*

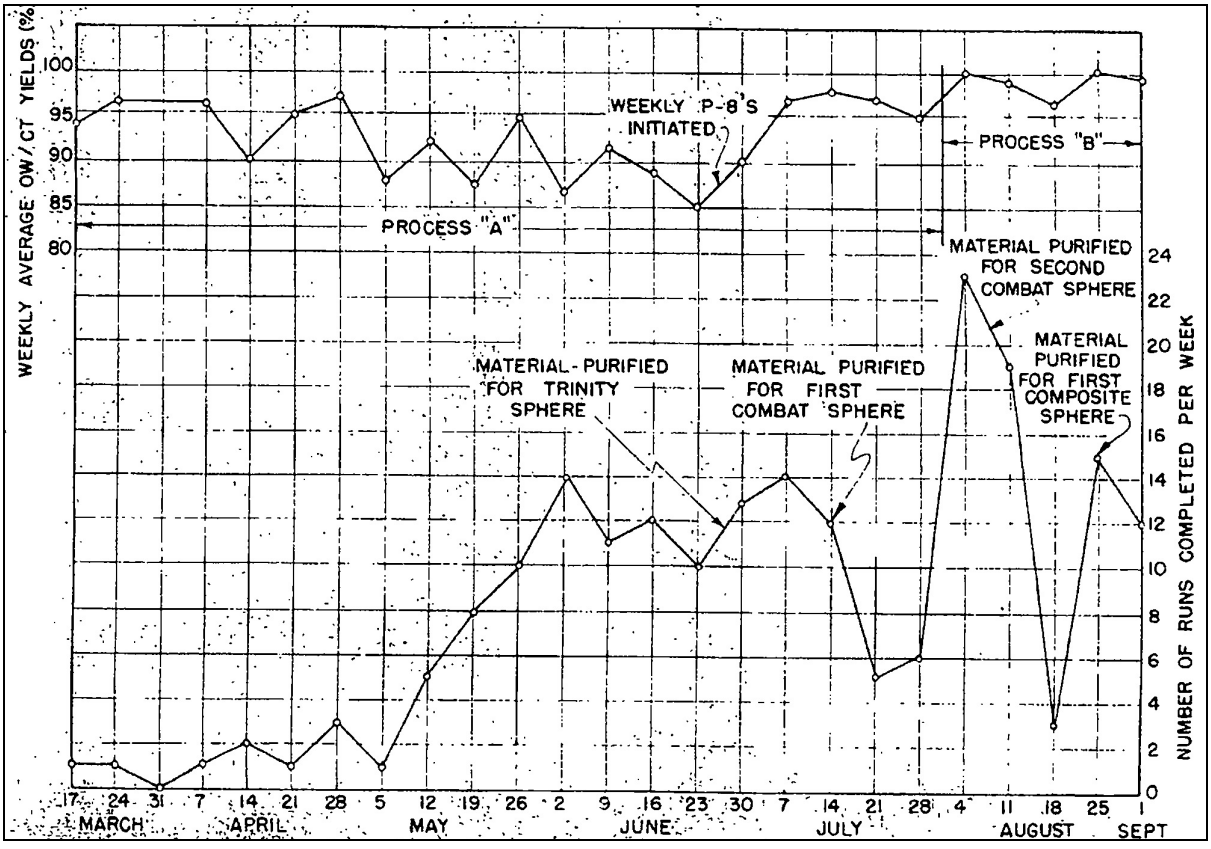


Fig. 4-12. Graph that documents purification of plutonium for four weapon cores in D-Building during 1945 (from Wahl 1947)

Release Estimates for D-Building Plutonium Processing

Because of the lack of effluent measurements for operations in D-Building during World War II, plutonium releases were estimated for each plutonium processing step using heuristics and experimental results compiled by the US Department of Energy in a document entitled "DOE Handbook – Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities" (USDOE, 1994). Although the Handbook is primarily intended to characterize accidental airborne radionuclide releases, experimental results presented therein lend themselves well to the characterization of releases within D-Building, as many plutonium processing operations were conducted in an open environment under similar conditions. The Handbook is broken into a number of sections characterizing releases of plutonium compounds through a number of mechanisms. To estimate plutonium releases from D-Building, each processing step was divided into a number of conceptual release mechanisms based on process descriptions contained in original LANL documents. For each conceptual release mechanism, an analogous experiment was identified in the Handbook, providing estimates of airborne release fractions (ARF) and respirable fractions (RF). These estimates were used to calculate the source term, which is the mass or activity of a radionuclide released during each conceptual release mechanism. While details of this assessment are documented elsewhere (Knutsen, 2007), methods and results are summarized below.

Within the release estimation process adopted by USDOE (1994), the source term is a product of a number of parameters:

$$\text{Source Term} = \text{MAR} \times \text{DR} \times \text{ARF} \times \text{RF} \times \text{LPF}$$

The material at risk, MAR, is defined as the mass of plutonium present at each conceptual release. For example, fluorination operations were carried out at a nominal scale of 160 g, which represents the MAR for this operation. The Handbook defines the damage ratio, DR, as the "fraction of the MAR impacted by the accident-generated conditions," and notes that a degree of interdependence exists between the DR and MAR, as some analysts choose to exclude radionuclides from the MAR that would not be affected by a given event. In this analysis, the MAR is defined to include only plutonium available for release in each process step, and the DR is set to unity in all cases. The airborne release fraction, ARF, is the fraction of plutonium aerosolized during each conceptual release mechanism. This parameter is highly dependant on the release mechanism, and ranges in this analysis from 1.3×10^{-7} for air blowing slowly over a solution of plutonium nitrate to 2×10^{-3}, representing a bounding estimate for liquid entrainment resulting from rapidly boiling solutions of plutonium nitrate. The respirable fraction, RF, represents the fraction of particles in a released aerosol small enough to be inhaled into the human respiratory system. The RF also

provides a method of estimating the fraction of aerosolized plutonium that could potentially reach the rooftop of D-Building via its ventilation system. The leak-path factor (LPF) is the fraction of aerosolized particles that could be transported through a containment mechanism.

In this analysis, the LPF is used as a means to estimate plutonium released from apparatuses with methods for containment in place. For example, production-scale purification and reduction processes were designed to mitigate aerosolized releases, and the LPFs for these processes were set to a small value based on professional judgment. The authors recognize that a high degree of uncertainty is associated with each of these parameters; a Monte Carlo simulation was therefore conducted to assess the sensitivity of each parameter to the overall D-Building source term. While the Handbook notes that estimated parameter ranges "should not be used as a basis for an ARF statistical distribution" and "specifically rejects citation as a defensible basis for such attempts," a Monte Carlo approach was used in this analysis as a means to assess parameter sensitivity and to provide some context to the range and uncertainty associated with release estimates.

Shown in Table 4-1 are source terms estimated for various plutonium processing steps, including purification, dry chemistry, and reduction, in addition to the recovery of plutonium from residues generated by each process. Note that source terms presented in Table 4-1 are calculated from nominal values of ARF and RF for conceptual release mechanisms presented in the Handbook. The total estimated source term of roughly 0.3 Ci is thus a nominal estimate, and a distribution of estimates shown in Fig. 4-13 reveals a fairly large uncertainty, with a 95%-ile estimate of over 1 Ci. The details of release estimates from one of the main plutonium process, plutonium recovery, are discussed below to illustrate the process that was used.

Releases from Plutonium Recovery

Recovery operations (Recovery) involved some open-air processing steps, and it was one of the most contaminated groups in D-Building (Duffy et al., 1945, Hemplemann et al., 1973). Recovery was conducted without effective containment mechanisms because of the large variety of plutonium-containing residues that Recovery received. This large variety of residues also made it exceedingly difficult in this analysis to characterize releases from all Recovery operations; as such, releases associated with more routine and well-documented recovery processes were emphasized instead. As shown in Table 4-2, the bulk of the plutonium-containing residues received for recovery were purification supernatants, metallurgical samples (plutonium metal, alloy, skulls, scrap), and materials from reduction/remelting of crucibles and slag (Garner et al., 1945).

Table 4-1. Summary of conceptual release mechanisms and source terms for several plutonium processes conducted from 1943 through 1945

Process / Conceptual release mechanism	Number of runs	Mass of Pu entering each run (g)	Mass of Pu processed (kg)	Number of releases per nominal run	Release Fraction	Release Fraction (ppm by mass)	Source term (mg)
Purification processes (160 g nominal scale)[1]	**207**	**151**	**31**	**6**	**6.4E-07**	**0.6**	**20**
Transfer releases				5	6.4E-07	0.6	20
Evaporation releases				1	4.2E-09	0.0	0.13
Recovery of process "A" purification supernatants[2]	**130**	**16**	**2.1**	**18**	**5.6E-05**	**56.3**	**116**
Transfer releases				12	2.2E-05	22.0	45
Steam releases (simmering)				2	2.9E-06	2.9	6
Liquid entrainment from sparging				1	2.5E-05	25.2	52
Filtration releases				3	6.2E-06	6.2	13
Recovery of process "B" and "C" purification supernatants[1,2]	**77**	**16**	**1.2**	**16**	**3.0E-05**	**30.4**	**37**
Transfer releases				12	2.2E-05	21.7	27
Steam releases (simmering)				1	2.6E-06	2.6	3
Filtration releases				3	6.1E-06	6.1	7
Dry Chemistry and Reduction			**29.16**	**7**	**2.9E-05**	**29.0**	**845**
Dry ignition release				1	4.6E-07	0.5	13
Transfer of plutonium oxide powder into fluorination reactor				1	2.8E-05	28.0	816
Fluorination of plutonium oxide powder				1	3.9E-08	0.0	1
Transfer of plutonium fluoride into glove box				1	3.9E-07	0.4	11
Transfer of plutonium fluoride within glove box				2	7.8E-08	0.1	2
Removal of plutonium button and transfer of MgO liner to Recovery				1	2.0E-08	0.0	1
Recovery of reduction crucibles			**0.7**	**13**	**3.2E-05**	**31.6**	**22**
Transfer of pulverized crucibles				1	3.9E-07	0.4	0
Transfer of solutions				8	1.9E-05	19.1	13
Steam releases (simmering)				2	5.8E-06	5.8	4
Filtration releases				2	6.3E-06	6.3	4
Peroxide recovery step			**7.6**	**8**	**6.1E-04**	**614.0**	**4680**
Transfer Releases				5	1.3E-05	12.8	97
Steam releases (simmering)				0	0.0E+00	0.0	0
Steam releases (boiling)				2	6.0E-04	598.0	4559
Filtration Releases				1	3.2E-06	3.2	24
Total source term:							**5721**
Total source term (Curies):							**0.35**

[1]Processes combined due to similar release mechanisms

[2]Not including peroxide recovery step

Table 4-2. Types of residues submitted for recovery, April–September, 1945 (Garner et al., 1945)

Type of Residue	Pu mass (g)	Fraction of Total Pu
Purification supernatants	3297	43%
Reduction liners, slag and remelt crucibles	684	9%
Metal, alloy, skulls, scrap	3334	44%
Pickling and plating residues	130	2%
Analytical and misc. residues	178	2%
Total:	7623	100%

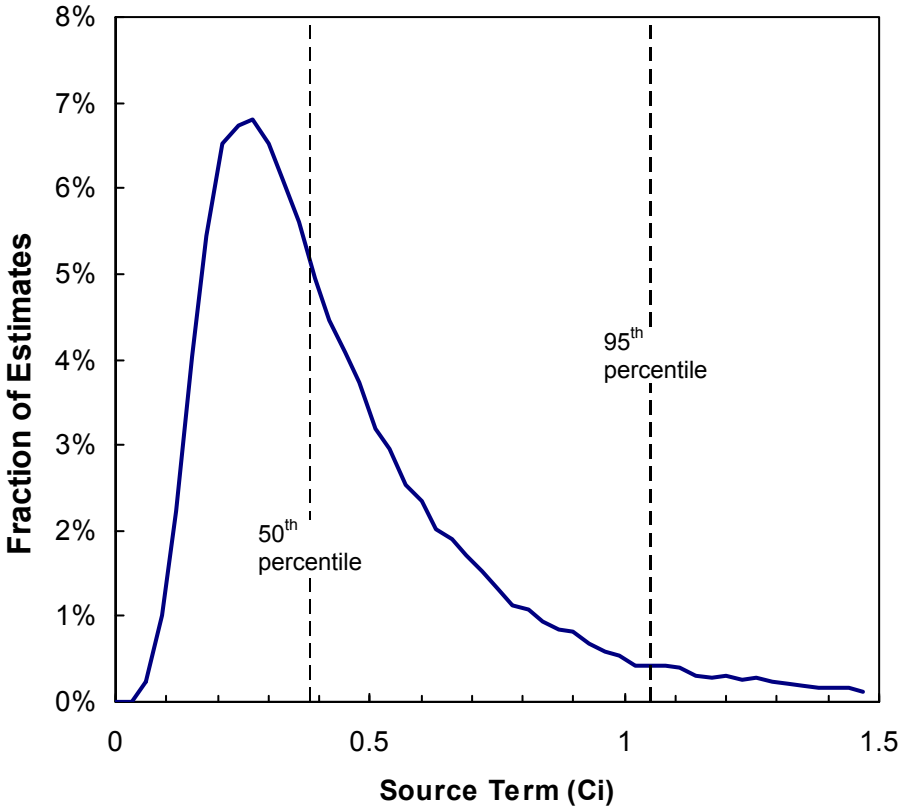


Fig. 4-13. A distribution of release estimates based on a sum of distributions associated with individual release mechanisms

As shown in Table 4-1 and depicted graphically in Fig. 4-14, the recovery of plutonium from the "A" purification supernatants consisted of 18 conceptual releases. Twelve of these releases consisted of "transfer" releases (Abbreviated "T"), which describe releases resulting from the entrainment of solutions into air while they are pumped from one process step to the next using a centrifugal pump or a steam jet (Duffy et al., 1945). For lack of more representative experimental data, this release was modeled as a liquid spill from a height of 1 m. ARF values for this release were based on experimental results (Sutter et al., 1981). In these experiments, ARF values from 1×10^{-6} to 1.6×10^{-5} were measured. For the purposes of this analysis, a log-normal distribution was selected with 1% and 99%-ile values set to represent the range of experimental values for ARF. The recommended RF value of 0.8 was chosen to reflect experimental results.

As shown in Fig. 4-14, there were three filtration steps (abbreviated "F"), with release mechanisms assumed to be similar to transfer releases. Some of the most hazardous steps in Recovery involved adding solid sodium hydroxide to solutions of plutonium salts. Because the dissolution of sodium hydroxide is highly exothermic, "considerable steam was released during the neutralization, resulting in a contamination hazard" (Duffy et al., 1945) [p. 17]. This release mechanism (labeled "Simmer" on Fig. 4-14) was modeled using data from experiments (Mishima et al., 1968) in which the fraction of boiling and simmering solutions entrained in flowing air was measured. Mishima et al. (1968) measured ARF values of 1.3×10^{-6} to 4.5×10^{-6}. For this analysis, a uniform distribution across this range was chosen. An RF value of unity was selected based on experimental results published in 2003 that include measurements of size distributions of entrained liquid droplets above boiling solutions and found that over 99% of entrained droplets were smaller than 10 μm (Cosandey et al., 2003).

A fourth release mechanism occurs when plutonium solutions were sparged with sulfur dioxide gas for 15-20 minutes, labeled "Sparge" on Fig. 4-14. This release mechanism was modeled using experimental results published in 1986 that summarize liquid entrainment across a range of superficial gas velocities (Borkowski et al., 1986). The bulk of ARF measurements appear to be log-normally distributed and fall between 10^{-5} and 10^{-4}. To capture these results qualitatively, a log-normal distribution with the 1%-ile and 99%-ile values of 2×10^{-6} and 1×10^{-3}, respectively, was selected for this analysis. The conceptual release mechanisms for recovery of plutonium from residual supernatants from the "B" and "C" purification processes were similar, but contained only one "simmering" release, and no releases from sparging, since the sulfur dioxide step was not needed for these residues.

As shown in Table 4-1 and Fig. 4-15, releases from the recovery of plutonium from reduction slag and crucibles are characterized by 13 release points, consisting of eight liquid transfer releases, two releases from simmering, two releases from filtration, and one release associated with the transfer of crushed crucibles and slag. A final step in all recovery processes, peroxide precipitation, was used to separate plutonium from a number of rare earth elements. Release mechanisms in this processing step, shown in Fig. 4-16, are associated with five liquid transfer operations, one filtration, and two boilings. There were two significant release mechanisms that occurred during the peroxide process. The first occurred when a 30% solution of hydrogen peroxide was added to a solution of plutonium nitrate. Upon addition, the hydrogen peroxide would effervesce, an effect that scientists tried to mitigate by cooling the mixture to 4°C. In 1945, it was documented that "the spray from the 'peroxiding' operation as carried out in Building-D was a major source of contamination" (Duffy et al., 1945)[p. 34]. An additional source of contamination presumably occurred in the final Recovery step, which involved boiling solutions of plutonium nitrate over a steam bath in 600 mL beakers, concentrating them into a "thick syrup" (Duffy et al., 1945)[p. 32].

Release Summary

Heuristics and experimental results compiled by the USDOE characterizing the accidental release of plutonium compounds were used to estimate the source term associated with plutonium production operations within D-Building from 1943-1945. The scope of this estimate was limited to releases from the Purification, Dry Chemistry, Reduction and Recovery groups during documented plutonium production operations. Concurring with anecdotal evidence in several LANL documents, this analysis suggests that the bulk of plutonium releases occurred from the Recovery group, as a result of open-air processing with minimal protection. Emissions resulting from the addition of hydrogen peroxide and from boiling of plutonium nitrate solutions were likely to have been particularly severe. This work resulted in a preliminary source term estimate of about 0.4 Ci (median) from processes that were included. This estimate is associated with a high degree of uncertainty, and true releases may have been in excess of 1 to 1.5 Ci. The preliminary 95^{th} percentile value is about 1.05 Ci. The uncertainty in these estimates is mainly due to the relatively sparse and marginally relevant experimental data. If further work estimating early airborne plutonium releases from LANL operations is undertaken, a portion of the work should be aimed at obtaining additional experimental data to support this estimate and reducing its uncertainty.

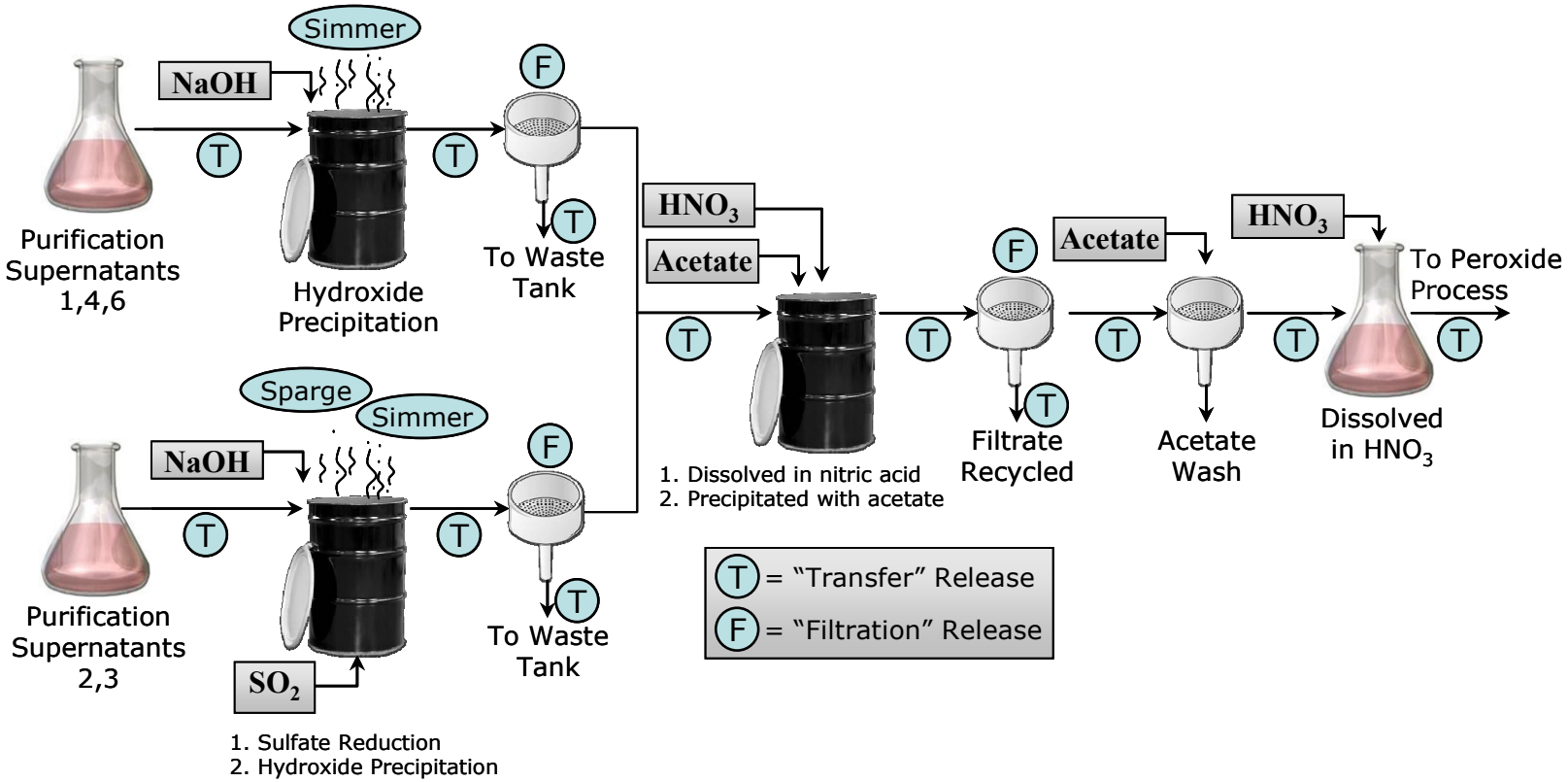


Fig. 4-14. Flow diagram of recovery release mechanisms during recovery of plutonium from residual purification supernatants

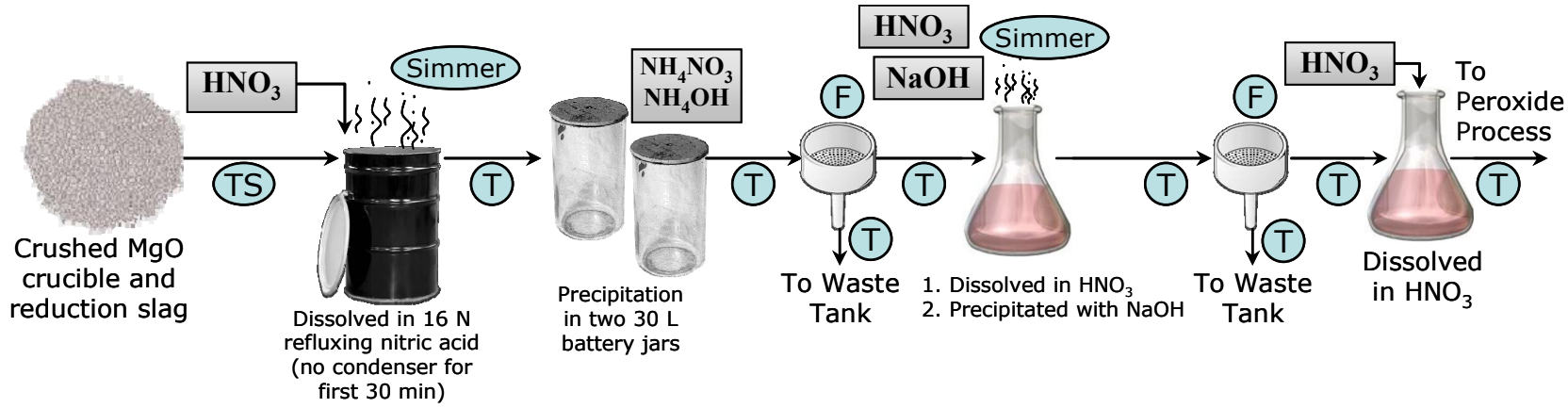


Fig. 4-15. Release mechanisms associated with plutonium recovery from reduction slag and crucibles. "T" = "Transfer" release mechanism (liquid); "TS" = "Transfer" release mechanism (solid powder); "F" = "Filtration" release mechanism; "Simmer" = "Simmering" release mechanism

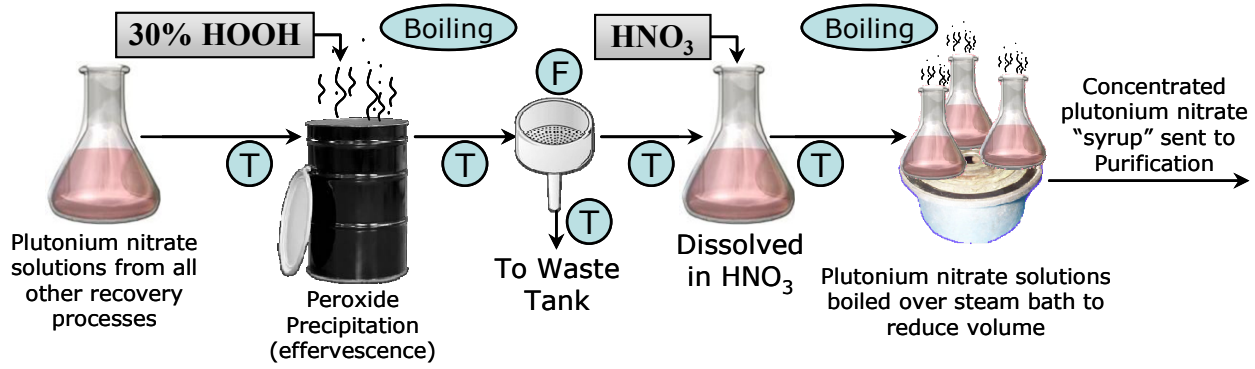


Fig. 4-16. Release mechanisms associated with the final recovery processes involving precipitation of plutonium nitrate with hydrogen peroxide

Indoor Measurements of Airborne Radioactivity as a Source of Information about Plutonium Releases from D-Building during World War II

One of the major operational areas from which plutonium releases were unmonitored was D-Building from 1943 until 1954. D-Building was the site of the process development and production of the plutonium components of the early nuclear weapons, analytical chemistry operations, and metallurgical research and development. Although major plutonium component production activities were transferred to new processing facilities at DP West Site in late 1945, D-Building continued to be an active and expanding facility until the Chemistry and Metallurgical Research (CMR) Building at TA-3 became operational around 1953.

Because D-Building was the first facility to process plutonium in visible quantities and fabricate weapon components, many of the environmental safety and health practices considered routine today had not yet been developed. Work that today would be carried out in glove boxes with multiple stages of HEPA filtration on the exhaust was instead conducted in open hoods or on laboratory benches. The working conditions present after multi-gram quantities of plutonium began to arrive at LANL in late 1944 rapidly deteriorated. In May, 1945, Wright Langham made a trip to Chicago to describe what steps were being taken at LANL to protect workers, including the recently developed monitoring methods utilizing bioassay. The push to develop and test the implosion device was considerable until the war was successfully concluded.

Although LAHDRA team members were unable to locate any stack monitoring records for D-Building for any portions of its operational period, workers frequently took measurements of the airborne concentrations of plutonium in various rooms and locations around D-Building. A lower bound estimate of plutonium releases can be made by using these concentrations, estimated room volumes, ventilation rates and some other assumptions.. Such an estimate, though, must be considered lower bound for several reasons. A large portion of releases apparently occurred from operational activities conducted in hoods, glove boxes, and other enclosures. Releases of the contaminated air in laboratories would be expected to be small compared to the unmonitored releases from work performed in laboratory hoods and other primitive confinement devices that exhausted directly to the environment via roof-top vents. Those releases are the subject of a separate analysis. Also, no measurements were made during the highly problematic startup period that used larger quantities of plutonium, roughly from December, 1944 to August, 1945. The measurements that were reported were made after the end of the war and after efforts were made to improve operational conditions within D-Building. Finally, the rooms that had plutonium measurements reported had results for less than 14% of all months, and many had only a few measurements during the entire period.

The monthly reports listed average (and at times, maximum) values recorded over the month. The reporting of data clearly separated rooms that housed enriched uranium activities from those that housed plutonium operations, and the room assignments do not appear to have been interchanged significantly over time. This separation of uranium and plutonium operations must have been intended to simplify the control and measurement of contamination, and was later continued at DP Site.

Measurements were made in 116 unique areas within D-Building; some were rooms with the same number, but differing letters (such as D-116 and D-116A), and others were hallways, change rooms, attics, and conference rooms. A total of 11,832 room-months of measurements (102 months times 116 rooms) could have been taken; however, a total of only 1,616 monthly measurements were reported for the entire time period that started in August, 1945.

The release of plutonium over time for the room air exhausted was calculated by the LAHDRA team using the following assumptions:

- 25% of room air volume is contaminated (heuristic estimate)
- 30 air changes per h (based on interview with LANL staff)
- Room Height = 10 ft for all rooms
- Detector intrinsic efficiency of 80%
- Filter Burial Factor of 1.602
- Counting Geometry Factor of 2

The last three assumptions result in a total factor of 4.005 for the conversion of air sample counting results from counts per minute per liter ("c/m/l" or c/min/L) to disintegrations per minute per liter ("d/m/l" or d/min/L).

The following equations were used to estimate the total release in a month for a given room:

$$(\text{d/min/L}) = (\text{c/min/L}) \times 4.005$$

$$(\text{d/min/h}) = (\text{d/min/L}) \times (\text{room volume}) \times 0.25 \text{ of room air contaminated} \times 30 \text{ air changes } h^{-1}$$

$$(\text{d/min released in a month}) = (\text{d/min/h}) \times (\text{d/month}) \times 24 \text{ h } d^{-1}$$

$$(\text{Ci released}) = (\text{d/min released}) / (3.7 \times 10^{10} \text{ d } s^{-1} \text{ Ci}^{-1} \times 60 \text{ s } min^{-1})$$

Room air concentration data were compiled from the CMR-12 monthly reports into a spreadsheet. Room volumes were calculated based on LANL drawings of D-Building. For areas with no defined volume, such as hallways, the volume of the section of hallway immediately adjacent to a laboratory was used

(with a further reduction associated with the assumption that only 25% of that volume is contaminated). At present, the limitation of the contamination to 25% of the room air and also to a small section of hallway is considered non-conservative, and produces a lower bound for the calculated releases.

To emphasize the degree of non-conservatism in this estimate, in 1948, LANL began to better understand the nature of releases from D-Building and glove boxes. In a study published in 1948, three rooms in D-Building were subjected to air sampling for a little more than one year (Kennedy, 1948). These rooms were used for processes that are not considered in the earlier section of this Chapter entitled "Release Estimates for D-Building Plutonium Processing." They included Room 134, which was used in 1947 for preparation of plutonium alloys and samples. The air in this room would have released 1.5 mCi of plutonium in 1947 using the room air model assumptions given above. The releases to room air comprise a small fraction of the total plutonium released, since many of the operations were conducted in dryboxes. The plutonium released to room air largely came from transfers of material through the room to other boxes and from handling the material in the open. Releases from the dryboxes during grinding and polishing to prepare metallurgical samples for analysis were unmeasured, and were another significant source of releases.

As mentioned above, the monthly reports yielded a total of 1,616 data points from 116 rooms over 102 months,meaning that over 14% of the cells in the spreadsheet have values. All the data in a given year was compiled into a distribution and tested. The data for each year followed a log-normal distribution, with no year showing a smaller residual than 0.93. These distributions could be used, if further evaluation of D-Building releases is undertaken, to stochastically estimate air concentrations for rooms each month for which no measurements were reported.

The sum of estimated releases over all months with reported measurements is 0.0109 Ci of alpha emitting radioactivity. Recall that this calculation is a partial representation of D-Building releases. In order to account for the rooms each month that have no results reported, additional assumptions must be made. This memo considers two possible approaches:

- One method would be to simply assume that the unmeasured rooms have the same average contamination as the average measured room. Using this assumption, a value of 0.08 Ci is obtained. This method essentially increases the total estimated for sampled rooms by a factor of the total of 11,832 room-months divided by 1,616 reported room-months.

- Many rooms had reports of low concentrations. An alternate approach is to assume that the average measured concentration in a given room is constant for that room. Under this

assumption, a total room air release of 6.12 Ci is obtained. There are rooms with high concentrations and few measurements that result in the larger release estimate under this approach, which assigns higher values to unmeasured periods than the average of measurements across all rooms.

This range of estimates (from 0.08 to 6.12 Ci) does not include the troublesome startup period of D-Building operations. Although this startup period represented 8% of the 102 months for which limited monitoring data are available, improvements in confinement devices might easily have afforded a factor of 10 reduction in air concentrations in a given laboratory by the time monitoring began. Thus, the early 8-month period during which multi-gram quantities of plutonium was being processed might have been an important period for environmental releases that this preliminary assessment does not address.

TA-21 (DP Site) Historical Plutonium Processing — DP West

In January, 1945, a serious fire that broke out in C-Building within the Original Technical Area raised concerns about the possibility of a fire in D-Building. This scare, plus a dramatic increase in the amounts of plutonium handled in D-Building and concerns about the need to house plutonium and polonium safely, led to planning of new facility to be called DP Site, and later, TA-21. DP West took over the plutonium production functions of D-Building. Most DP Site facilities were constructed in 1944-1945, and the necessary process equipment was installed during this time as well. Operations appeared to have started near the end of November, 1945 (Meyer and Schulte, 1944-1956).

The primary functions of DP West were to: 1) produce metal and alloys of plutonium and other transuranic elements from nitrate solution feedstock; 2) fabricate these metals into precision shapes; 3) provide and install protective claddings; 4) measure the chemical and physical properties of these metals and alloys; and 5) recycle scrap or materials used in experiments (Valentine et al., 1982).

Fig. 4-17 shows the early layout of DP West (Christenson and Maraman, 1969). Photos of DP West are shown as Fig. 4-18 and Fig. 4-19. Buildings 2 and 3 housed wet chemistry processes, and Buildings 4 and 5 housed dry chemistry processes. Building 12 was the main filter building for exhausted air.

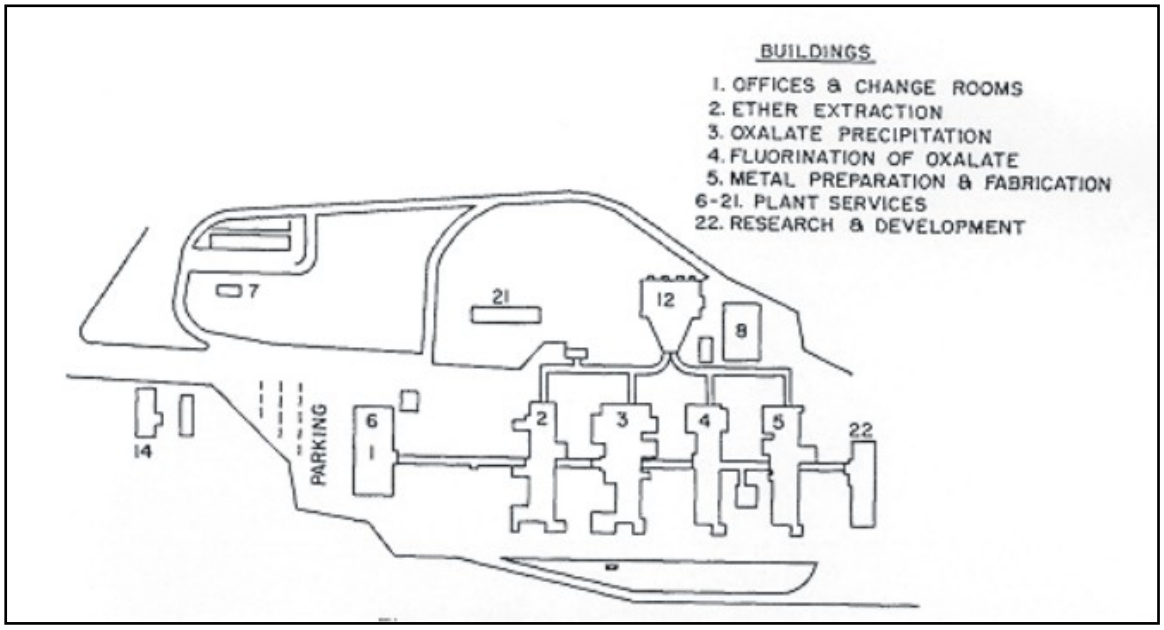


Fig. 4-17. Early DP West Site Building Layout and Main Functions

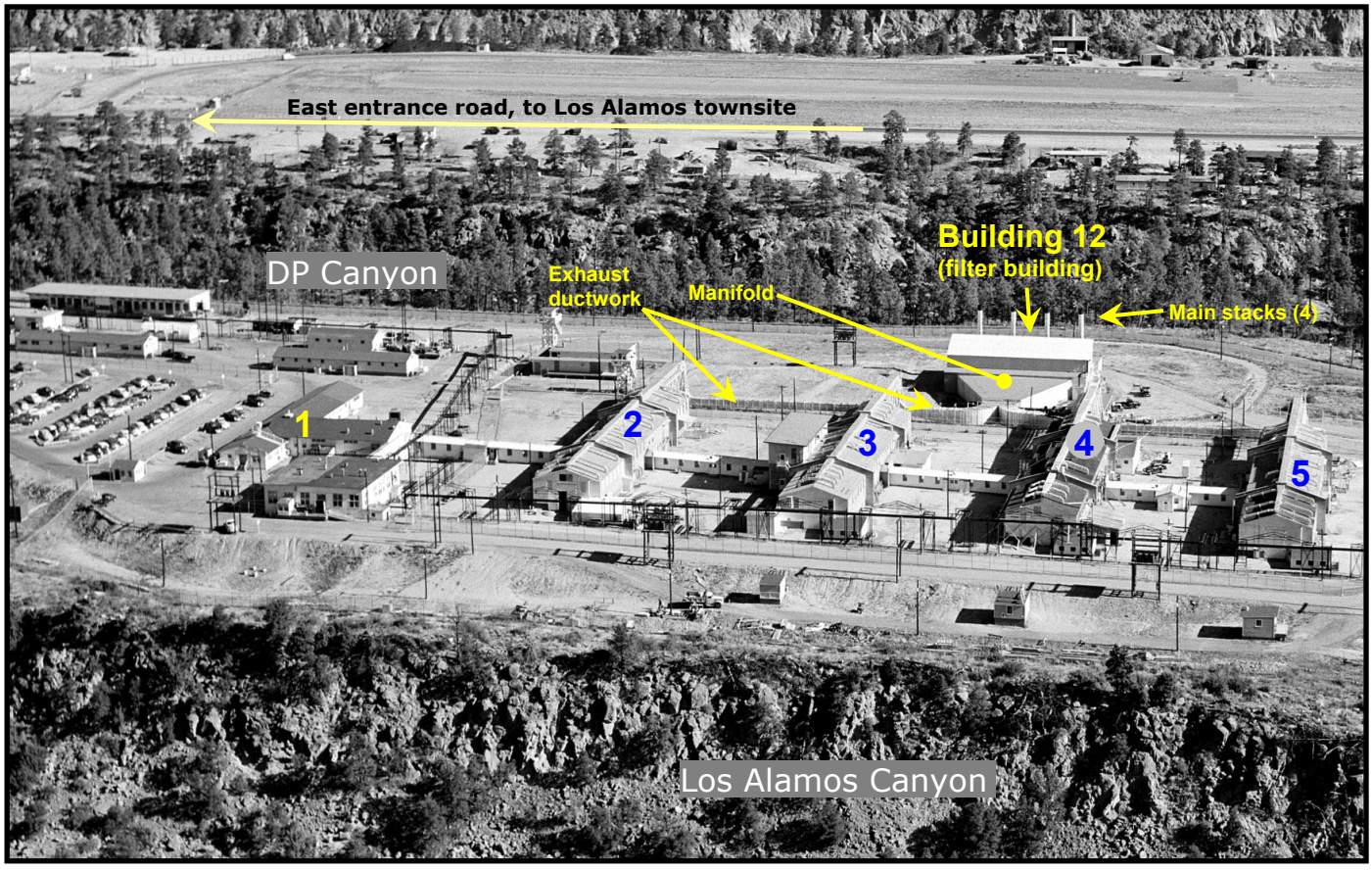


Fig. 4-18. DP West site, looking north, date unknown. Plutonium process buildings 2, 3, 4, and 5 are labeled, as are the filter building (12) and associated ductwork, manifold, and stacks. *From photo IM-9:15926 courtesy of LANL.*

Fig. 4-19. Primary buildings of DP West on 16 May 1947. *Photo courtesy of LANL (IM-9: 05426)*

Fig. 4-20 presents a flow diagram of the process used in early DP West Site operations for processing plutonium and producing atomic weapon components (Kennedy, 1947).

Following are summaries of the activities performed in each major building at DP West:

- Building 2 (TA-21-2)– housed gloveboxes for dissolution and recovery of plutonium and storage of ^{241}Am wastes. The building housed a scrap incinerator, solvent extraction columns, and a liquid-waste loading area. On December 30, 1958, a criticality accident occurred in Building 2 South involving separated phases in a plutonium process tank. The operator (Cecil Kelley) died 36 hours later.

- Building 3 (TA-21-3)– housed the oxalate precipitation operations.

- Building 4 (TA-21-4)– housed some development laboratories for plutonium research from 1945 to 1948, at which point the laboratories were converted to production areas for enriched uranium hydride. In 1960, the hydride equipment was removed so that a hot cell could be added for examining irradiated plutonium and enriched uranium fuel elements. In 1965, two glovebox lines were added to support the ^{238}Pu metal production. The above programs were part of Rooms 401 and 401E on the north end of the building (Valentine et al., 1982). Rooms 403, 404, 405, 406, and 407 also had gloveboxes that were used for ^{239}Pu and ^{238}Pu metal preparation during these early years.

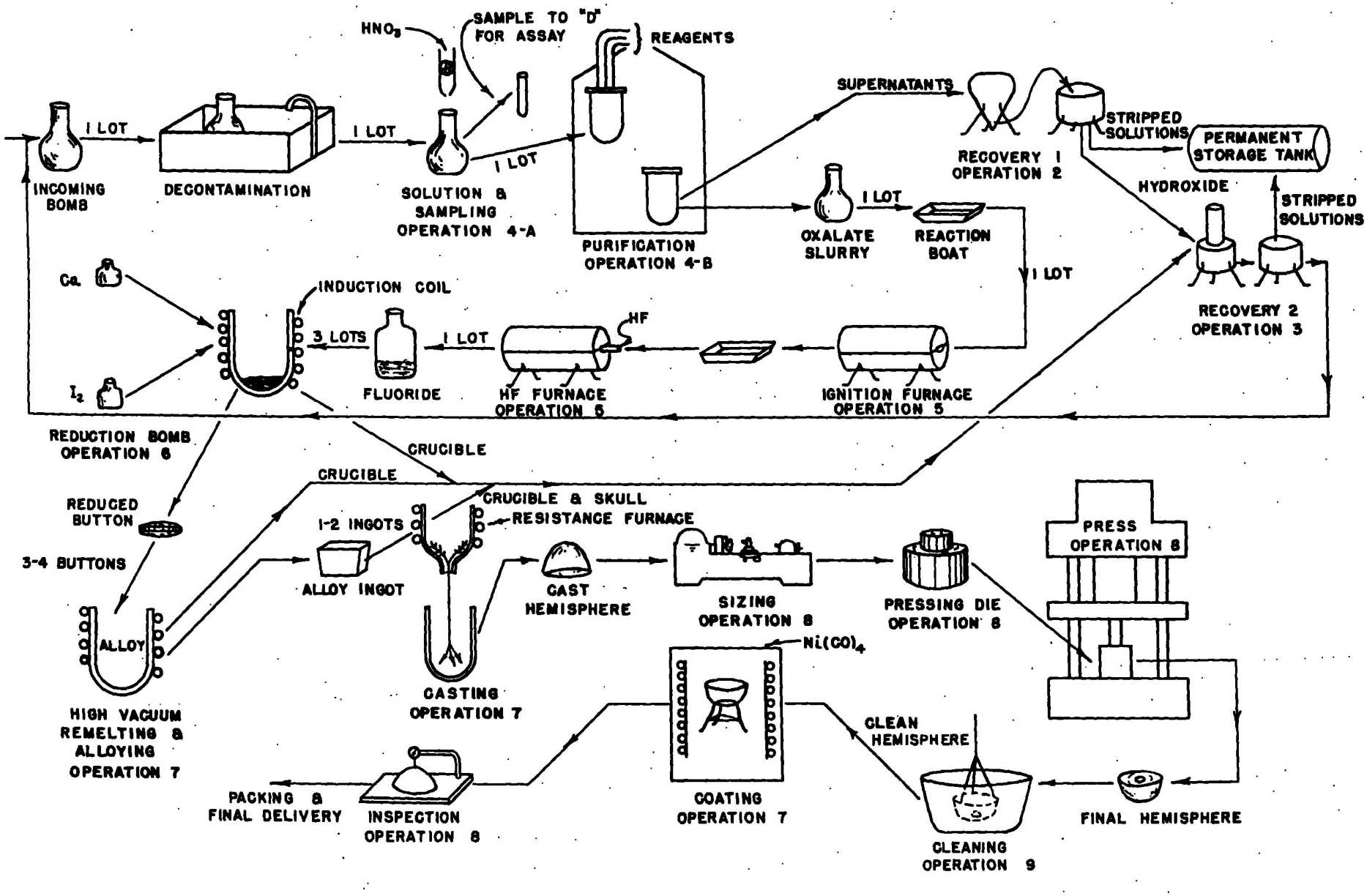


Fig. 4-20. A flowchart of early plutonium processing operations at DP West Site (from Kennedy 1947)

- Building 21 (TA-21-21) – was a vault for storing uranium and plutonium metal.

- Building 33 (TA-21-33) – housed research efforts regarding collecting additional plutonium from waste streams.

- Building 150 (TA-21-150) – was built in 1963 as a plutonium fuels development building (Repos. No. 2344). This building was built next to Building 5. Some of the programs the building supported included: 1) the development of ^{238}Pu heat sources for space electric power applications; 2) investigations of various ceramic materials containing plutonium for use in the Liquid Metal Fast Breeder Reactor (LMFBR) program; and 3) the development of ^{238}Pu fuels for isotopic powered heat sources for powering artificial organs (Valentine et al., 1982).

  In an incident in DP West Building 150 on October 7, 1970, a sealed capillary broke, resulting in the release of a reported 10 ug of ^{238}Pu up a vent. Resulting concentrations were estimated to be 2,800 times the AEC maximum permissible concentration (MPC) for insoluble ^{238}Pu. Air samples were analyzed from the DP fence line, near private housing just west of the west end of the airport runway, and at the airport terminal air particulate sampler. Maximum reported air concentrations were 1.27×10^{-14} $\mu Ci\ mL^{-1}$ ^{238}Pu at housing near the airport runway and 0.29×10^{-14} $\mu Ci\ mL^{-1}$ ^{239}Pu at the DP Site fence (Kennedy, 1970, Meyer, 1970).

- Building 210 (TA-21-210) – housed additional research activities on the properties and uses of plutonium.

DP West Air Handling and Stack Air Sampling

Buildings 2, 3, 4, and 5 each had an intake air fan. The air was filtered and then distributed by a system of ducts that entered the rooms of the buildings at the ceiling. The exhaust air left the rooms by another system of ducts that lead into a large common duct located on the roof of each building. All dryboxes and hoods for each building were vented into this common exhaust duct (LAB-CMR-12-60).

These common ducts converged into a large manifold in Building 12, where the air was supposed to mix to a uniform concentration. The air then passed through the precipitrons. The precipitrons were electrostatic units that used electric fields to ionize and capture particles. The air then passed through a single bank of American Air Filter Company type PL-24 filters (Christensen et al., 1975). The air was finally discharged by exhaust fans out of four stacks that were approximately 57 feet tall. In the early days of DP West, the exhaust air was sampled in the common exhaust ducts, the Building 12 manifold,

and in each stack. Modified "Filter Queen" vacuum cleaners were used to sample the exhaust air at these locations (Maraman et al., 1975).

The DP West Site exhaust treatment systems were improved over decades of site operations (Maraman et al., 1975). A single bank of HEPA filters was installed in the DP West Site's combined process exhaust system in 1959. The process exhaust system was separated from the plant exhaust system at that time. As part of the 1959 work, a cleaning of the room exhaust plenum resulted in a spike in measured airborne releases. The room exhaust plenum was again cleaned in 1973, leading to another spike in releases. Two banks of HEPA filters were installed in the process exhaust system in 1973, the same year in which a single bank of HEPA filters was installed in the room air exhaust system.

More Recent Plutonium Processing

In 1969, the decision was made to build a new facility, TA-55, called the Plutonium Facility Site. Plutonium processing and plutonium metallurgy research are done at this site, which is also known as "PF Site." Operations at TA-55 include processing and recovery of ^{239}Pu from scrap materials, recycle, metal production, metal fabrication, and research & development. This facility was also the site of special isotope separation research. The SIS-III was designed to provide special plutonium isotopes for LANL weapons research. The site also had responsibility for manufacturing heat sources for weapons-related programs (Cochran et al., 1987).

Plutonium has also been processed at TA-3, the new Core Area: [a.k.a. "South Mesa Site"]. The Lab's main technical facilities moved here from TA-1 in 1953. Areas at TA-3 that likely involved plutonium processing include:

- TA-3-29 Chemical and Metallurgical Research (SM-29) (has Wings 1-9).
- TA-3-32 Cryogenics
- TA-3-34 Cryogenics
- TA-3-35 Press Building
- TA-3-39 Technical Shops
- TA-3-40 Physics
- TA-3-65 Source Storage (SM-65)
- TA-3-66 Sigma Complex
- TA-3-102 Tech Shops (handles beryllium, uranium, lithium per Repos. No. 225)
- TA-3-141 Rolling Mill
- TA-3-184 Occupational Health
- TA-3-216 Weapons Test Support
- TA-3-700 Acid Neutralization and Pump Bldg (also known as SM-700).

As of 1969, the CMR Bldg, except for its Wing 9, was used for laboratory work on small quantities of uranium and plutonium. Effluents were filtered through Aerosolve 95 filters. Wing 9 contained hot cells handling irradiated uranium and sometimes plutonium. Effluents may also have contained mixed fission products, including iodine. HEPA and charcoal filters were reportedly used for treatment. Filters were counted for both alpha and beta radiation.

Stack FE-19 of the CMR Building serves the glove box processes and rooms on the south side of Wing 3. As of March, 1980, the exhaust treatment system had a demister, one stage of M-80 prefilters, and one stage of American Air Filter Continental 2000 filters (that is, bag filters with published 85% efficiency for 0.3 μm DOP). Prior to July, 1976, the system included Aerosolve 95 filters.

Since early 1974, FE-19 has been major source of plutonium at LANL (up to 99% of the total in 1980). Releases from FE-19 began to increase during February, 1979, when two filters tore. During filter change-out, flow reversal sent 143 μCi of Pu up FE-20 stack (Stafford et al., 1979-1982). Testing in February, 1980 revealed that FE-19 filters were only 29.3% efficient. The release from FE-19 between January 19 and January 26, 1979 was 91 μCi, which was greater than the total release for this stack in 1978.

Alpha activity in liquids flowing into the TA-50 waste treatment plant rose sharply in the years leading up to 1973 because of increased use of ^{238}Pu at the SM 29 building in TA-3. Concentrations at times reached 0.001 μCi/cc [pages from microfiche: TR7831, Envelope 51, dated 5/9/73].

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Chapter 5: Reactor Development and Operations at LANL

When it was first established, Technical Area 2 (TA-2), also known as Omega Site, was used for both nuclear criticality experiments and as the location for the Water Boiler reactor. Assembly of the first Water Boiler (the LOPO model) began in late 1943. In April, 1946, nuclear criticality experimentation was relocated from TA-2 to TA-18 (Pajarito Site). Construction of the plutonium fast reactor (Clementine) began in August of that year, and from then on Omega Site was used primarily as the location for reactors used for neutronics experiments and isotope production. Over its history, TA-2 has housed the operations of three reactors: the Water Boilers (three different versions), the plutonium fast reactor (Clementine), and the Omega West Reactor (OWR). No reactors have operated at TA-2 since the OWR shutdown in December, 1992. The Water Boiler was deactivated in June, 1974, and the Clementine reactor was deactivated in December, 1950 following four years of problematic operation.

The Water Boiler Reactors

[Much of the following was adapted from "Early Reactors" by Merle E. Bunker (Bunker, 1983). Other references are as cited.]

Fig. 5-1. A view of Omega Site, TA-2, from above

During the Manhattan Project, a reactor was needed for confirming critical mass calculations, measuring fission cross-sections, and determining the neutron scattering and absorption properties for materials being considered for moderators and reflectors in the first atomic bombs. Enrico Fermi advocated constructing a homogeneous, liquid-fueled reactor, using enriched uranium. Three versions were eventually built, all based on this concept. For security reasons, these reactors were all referred to as "water boilers." The name was appropriate, since dissociation of the fuel solution would occur in the higher-power versions, giving an appearance of boiling.

The first water boiler was assembled in late 1943 at Omega Site. At that time, the fuel for this reactor (14%-enriched uranium) consumed the nation's total supply of enriched uranium. Two machine gun posts were therefore placed at the site to ensure its security. The first water boiler was called LOPO (for

low-power) because its power output was virtually zero, allowing for a simple design and eliminating the need for shielding. The fuel for the LOPO was an aqueous solution of enriched uranyl sulfate. The fuel was contained in a one-foot diameter spherical shell of stainless steel, surrounded by a reflector consisting of beryllium blocks on a graphite base. Control and safety rods passed through the reflector assembly. The fuel solution (known as the "soup") was pumped into the steel shell from a conical storage basin located beneath it. Since the system was intended for low power, no provisions for cooling were included. The LOPO achieved initial criticality in May, 1944.

The purpose of the LOPO was to determine the critical mass of a simple fuel configuration and to test the water boiler concept. With these goals met, the LOPO was dismantled to make way for a second design that could be operated at a power level of up to 5.5 kW, and thus serve as a neutron source needed for cross-section measurements and other studies. This second version was called the HYPO (for high power). The fuel solution was changed from uranyl sulfate to uranyl nitrate, and cooling coils were added within the shell. A tube passing through the shell (called the Glory Hole) was also added to allow for placing samples in the region of maximum neutron flux. The reactor was surrounded with a concrete shield. The HYPO began operation in December, 1944, and was used for many of the key neutron measurements needed in the early days of atomic bomb design.

In March, 1951, significant modifications to the HYPO were completed in response to demands for higher neutron flux and more research capability. These modifications allowed the water boiler to operate at power levels up to 35 kW. This modified version of the HYPO was dubbed the SUPO. Modifications made in the conversion of the HYPO to the SUPO included:

- Installation of additional cooling coils within the fuel vessel for greater cooling capacity.
- A significant increase in the enrichment of the uranyl nitrate fuel solution, from 14% ^{235}U to 88.7% ^{235}U.
- The beryllium oxide portion of the reflector was replaced with graphite to allow for more rapid shutdown.
- A gas recombination system was connected to the reactor vessel to eliminate the explosion hazard posed by the radiolytic dissociation of hydrogen and oxygen from the fuel solution. The water formed in the recombination chamber of this system was returned to the fuel vessel.

To reduce the emission of short-lived radioactive gasses from the Water Boiler, a delay line was installed. Before the installation of the delay line, it reportedly could not be determined how much ^{131}I was present

because of masking by Rb-88. Charcoal samples reportedly showed that essentially no ^{131}I was present before or after the delay line was installed [3/98 memo J. Margo Clark to Ken Silver].

The SUPO Water Boiler experienced a water leak into its moderator shield, and had to shut down in 1973. Its stack was found to be contaminated with ^{137}Cs (Personal communication, LANL Site Tour, 1998). Contamination in the reactor had migrated to the bioshield. SUPO was operated almost daily until its deactivation in 1974. Like its predecessors, it was used extensively for cross-section studies and other neutron measurements. However, it was also used for studying reactor physics (perturbation effects) and for biological research.

Planning for Decontamination and Decommissioning (D&D) of the SUPO facility began in July, 1988. The physical decommissioning process was completed in April, 1990, with the facility (TA-2-1-122) subsequently being released to the Isotope and Nuclear Chemistry division (Montoya, 1991, Paternoster and Kirk, 1991).

The Plutonium Fast Reactor (Clementine)

[Much of the following was adapted from "Early Reactors" by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983). Other references are as cited.]

The plutonium fast reactor was proposed and approved in 1945 as a high-intensity fission neutron source that could also be used to assess the suitability of plutonium as a reactor fuel. Since a fast reactor requires no moderating material, the reactor could be of small size. The site chosen for the fast reactor was adjacent to the water boiler building at Omega Site. Construction began in August, 1946, during which time the reactor was dubbed Clementine, after the song "My Darling Clementine." The fuel for the fast reactor was in the form of small rods clad in steel jackets. The rods were installed in a steel cage through which the coolant, liquid mercury, flowed at a rate of approximately nine liters per minute. Flow was maintained via an electromagnetic pump. The fuel cage was surrounded with a six inch thick natural uranium reflector, most of which was plated with silver to reduce corrosion. The uranium reflector was surrounded by an additional steel reflector six inches thick, and finally by a four inch thick lead shield. Reactor (reactivity) control was achieved by inserting uranium fuel rods into the cage – a positive reactivity control method as opposed to the negative reactivity control method typically used in reactors.

Initial criticality of the fast reactor was achieved in late 1946, though its design power of 25 kW was not reached until March, 1949. During this interim period, measurements were made at low power, including determining the neutron energy spectrum, reactivity effects, cross sections, etc. Changes in the control system were also made during this time, as more experience operating a fast reactor was gained. In

March, 1950, following nearly a full year of operation, the fast reactor was shut down to correct a malfunction in the control and shim rod operation. During this shutdown, a ruptured uranium rod was discovered and replaced. Operation resumed in September, 1950, and continued until late in December, when it was determined that a plutonium fuel rod had ruptured and released plutonium into the mercury coolant. The hazard created by this condition and the identification of serious abnormalities in the uranium reflector prompted the decision to permanently shut down and disassemble the reactor. One of the lessons learned from experiences with the fast reactor was that mercury was unacceptable as a coolant because of its poor heat transfer properties and other concerns.

When Clementine was decommissioned, its parts were stored in a hutment at Area C, and are believed to have been subsequently buried there (LANL, 1993). The disposal location of the mercury coolant is not known (LANL, 1993).

The Omega West Reactor (OWR)

[Much of the following was adapted from "Early Reactors" by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983). Other references are as cited.]

With the early demise of the plutonium fast reactor, a replacement was needed for neutron measurements in various laboratory activities. After evaluating the options available at that time, LANL officials concluded that a design patterned after the Materials Test Reactor (MTR) at the Idaho National Laboratory would be most effective. A reactor designed to use the MTR's plate-type fuel elements, which had already undergone extensive testing, meant core design and licensing could be expedited. The conceptual design for the new reactor was completed by the end of 1953. The core was to sit at the bottom of a water tank eight feet in diameter and 24 feet high. The reactor would be cooled by water flowing at 3500 gpm. The proposed power level was five MW, but the shield was designed so that a power level of 10 MW could be tolerated. To save time and money, the reactor was built in the same room that had previously housed the plutonium fast reactor.

The OWR reportedly got an exemption from 10 CFR 100 reactor-siting criteria. The OWR was a small, low pressure, low temperature research reactor. Natural convective circulation of the reactor pool water was reportedly sufficient to cool the reactor. The maximum credible accident that was assessed would release 822 Ci of ^{131}I to the air, along with 10,900 Ci of other iodines, 168 Ci of ^{131}Xe, and 153,000 Ci of other rare gases. Doses were calculated at a Residential Area (0.4 mi cross canyon), Skating Rink (1.9 mi up canyon), and State Road 4 (4.0 mi Down Canyon). Maximum doses calculated by LANL personnel for this accident were reportedly 57 rem to thyroid and 22 rem whole body at State Road 4 (LASL, 1993).

Construction of the new reactor began in mid 1954. Initial criticality was achieved in July, 1956, and a few months later the Omega West Reactor (as it became known) was operating at 1 to 2 megawatts (LASL, 1956). In May, 1966, new operating limits were established that allowed the maximum operating power level to be increased to 6.5 MW (Thomas et al., 1993). A modification to the OWR's cooling system allowed its maximum operating power level to be increased to eight MW in August, 1967. The technical specifications for the OWR prescribed a Limiting Safety System Setting (LSSS) of 11 MW. The OWR's safety limit was 14 MW (Thomas et al., 1993).

The OWR reportedly had an iodine-125 production loop, and, at times, the reactor operated essentially around the clock on an "Iodine Production Loop schedule." "OWREX" capsules were placed in the reactor (e.g., OWREX-5 insert, OWREX-8 insert around 1966). These capsules evidently contained fuel and sodium. Fission gas traps and sweep-gas monitor detected leaks of capsules on several occasions (LASL, 1967a).

In December, 1992, the combination of an unusual occurrence resulting in a challenge to a safety system and the discovery of underground piping coolant leaks prompted the shutdown of the OWR. The unusual occurrence took place on December 11, 1992, when human error resulted in the reactor power rising to an administrative control limit of 9.6 MW, prompting an automatic shutdown of the reactor. The investigation report compiled for this event identified three root causes for the incident, but concluded overall that conduct of operations at the OWR facility was inadequate (Thomas et al., 1993). The three root causes specifically identified in the report were: task performance errors on the part of various personnel, inadequate procedures for removing samples from the reactor, and inadequate procedures and policies for ensuring reactor control would not be compromised in the event of off-normal conditions (Thomas et al., 1993).

In 1994, all of the fuel and control blades were removed from the OWR, and the facility was placed in a safe shutdown mode (Burns et al., 1996). Inspection of the fuel elements conducted during the defueling operation showed that no fuel damage had occurred. All coolant was drained from the reactor vessel. A preliminary characterization in support of planning decommissioning activities was conducted in 1995 (Burns et al., 1996).

OWR operated routinely operated 120 hours a week during its first 16 years. Usage dropped off to around 40 hours per week thereafter until the reactor was permanently shut down. Research conducted at the OWR included: cross-section studies, measurement of weapon yields (via comparison fission counting), neutron radiography, condensed matter studies (via neutron scattering), testing of power

reactor components, testing of power reactor fuels, tests of plasma thermocouples, neutron activation analyses, and radioisotope production.

The Omega Stack

A memo from Hornberger to Hoffman dated May 25, 1945 (Hornberger, 1945) describes the off-gas line from the Water Boiler (HYPO), and reports exposure rate readings made beneath and to the sides of the line. These readings are given in terms of the time in hours a worker would need to be at a location to receive an exposure equal to the daily limit at that time. The first part of the line (see Figure 5-2) is described as being hung on tree supports and ascending the canyon wall. The last half of the line had four points at which it sagged to the ground. Breaks in the line were noted at 75 yards and 25 yards from its exhaust end. There is no mention of a stack. The memo includes a hand-drawn figure (Figure 5-2) showing the off-gas line relative to the Water Boiler building and the mesas north and south of Los Alamos Canyon.

LANL document(LASL, 1947), "Manhattan District History, Volume II," states that "External radiation hazards [at LANL] were, for the most part, well controlled. However, arrangements for discharge of fission products from the Water Boiler were most unsatisfactory and represented a potential and serious health hazard. The gaseous materials were merely discharged near ground level at the top of the mesa just to the south of Los Alamos Canyon. Warning signs were inadequate and the area was accessible to any casual visitor. Intensities in excess of 50 r/hr were repeatedly measured near the discharge point when the boiler was in operation."

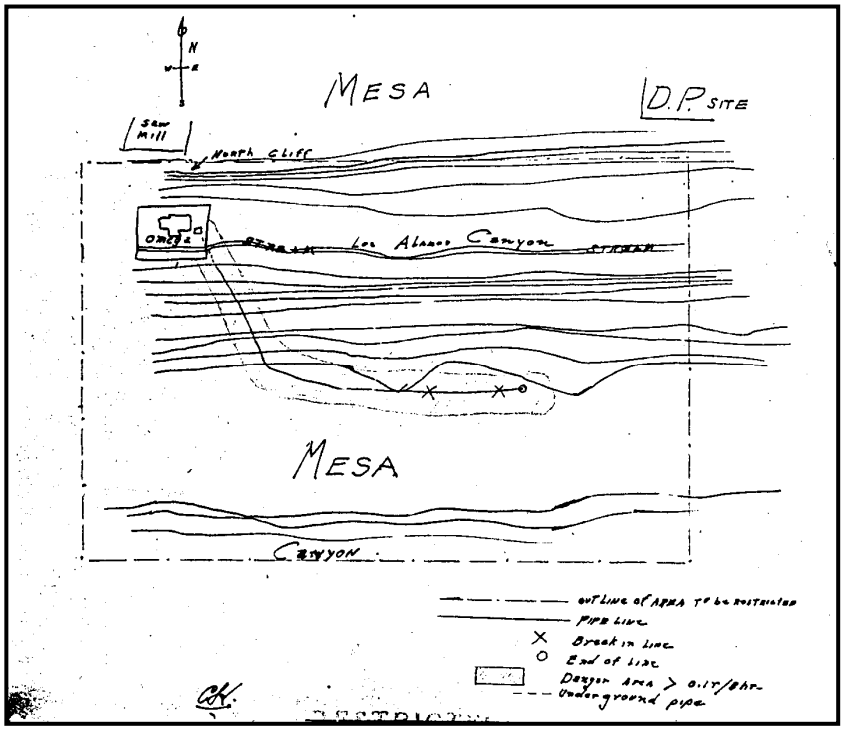


Fig. 5-2. Sketch of the Omega Site off-gas line

A memo from Blackwell and Littlejohn to Hempelmann dated April 24, 1947, reporting their discovery that the offgas line from the Water Boiler (HYPO) was "shattered" at about 100 feet prior to the "outlet" (stack), which was located in the top of a pine tree (Hornberger, 1945). The memo surmises that the line became brittle from the off- gas and was broken due to swinging caused by recent high winds.
In later years, a 150-ft tall stack on South Mesa was used to ventilate the OWR thermal column region and experiment. The flow rate in this stack was reportedly 880 $ft^3 min^{-1}$. Approximately 600 Ci of ^{41}Ar was reportedly discharged per year (Unknown, 1973). In 1968, a charcoal filter was added in the vent line from the OWR surge tank to the 150-ft stack (Warner, 1972).

The original stack for OWR effluents was also described as a "flexible pipeline" that ran up the mesa and was attached to a tree. Exposures to a nearby "Trailer Village" were a concern (Hornberger, 1945). This original effluent line was Tygon tubing that was laid on the ground or draped on trees. It led to a pipe that was fastened to a pine tree. Eventually a buried stainless steel line and a stack were put into place.

On June 11, 1957, a memo from D. D. Meyer to D. Ritter (ENG-4) requesting removal of the barbed wire exclusion fence that kept people 50 feet or so away from the Omega stack (Meyer, 1957b). It also states that the "old" Omega stack is still located in the top of a dead tree just outside the fence

surrounding the current stack. is the memo requests that the old stack be taken down and sent to the "contaminated waste pit." A second memo prepared by Mr. Meyer, also dated June 11, 1957, states that P-2 plans to connect the off-gas system for the OWR to the existing system for the Water Boiler (SUPO)(Meyer, 1957a). This action was completed between September 20, 1957 and October 20, 1957 (LASL, 1957).

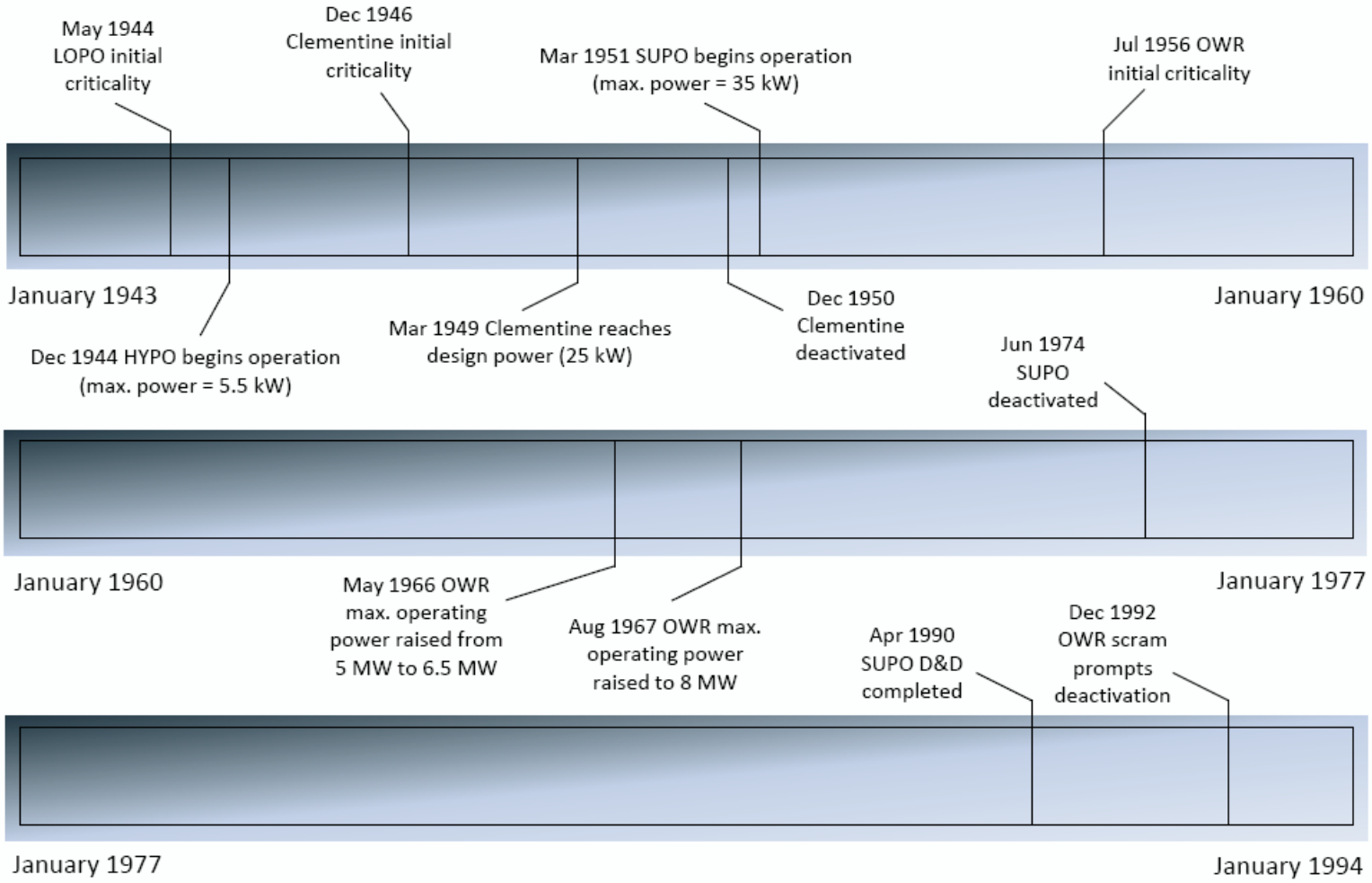
A charcoal filter was installed in the vent line for the OWR surge tank air space in 1968 (Warner, 1972). The filter was installed as a precaution against a large radioiodine release that might otherwise have occurred in the event of a fuel element or experiment failure.

Hankins (1963) describes the Omega stack as being 150 feet long and having an inside diameter of eight inches (Hankins, 1963). The two inch (inside) diameter vent pipe from the reactor to the stack was 1100 ft long. The vent pipe included a settling tank and two water traps to collect water that condensed out of the effluent. The delay time of gas in the vent pipe was originally 2.3 d, but the addition of the vent line from the OWR cut this time to about 8 to 10 hours. The effluent in the vent pipe flowed to the stack at a rate of about 100 to 200 $cm^3\ min^{-1}$, resulting in a dilution factor of about 100,000 in the stack. The stack flow rate was measured to be 845 $ft^3\ min^{-1}$ at a velocity of 2400 ft min^{-1}.

Per Hankins (1963), the combination of the recombiner, the long length of the vent pipe, and the low flow rates resulted in the particulate component of the effluent consisting of very small particles. It is reported that 65% were less than 0.05 μm, 93% were less than 0.1 μm, and none were larger than 1.0 μm.

A timeline of events of operational significance for Omega Site reactors is presented as Figure 5-3.

Figure 5-3: Timeline of Operational Events for Omega Site Reactors



LAPRE I and LAPRE II

The Los Alamos Power Reactor Experiment (LAPRE) explored the use of a homogeneous reactor fuel consisting of highly-enriched UO_2 (93.5% ^{235}U) dissolved in 95% phosphoric acid. Such a reactor system was thought to show promise for portable power sources for military applications if a method for containing the highly-corrosive fuel solution could be found. Consequently, two test reactors (LAPRE I and LAPRE II) were constructed and operated at Ten Site (TA-35) by K-division personnel between 1955 and 1960. LAPRE I was located in one of the hot cells of the main laboratory building. LAPRE II was located outside the main building in an underground enclosure tank. The purpose of the LAPRE I reactor experiment was to study the use of phosphoric acid solutions of uranium for a high-temperature reactor fuel in a simple, compact design in which the reactor core and the heat exchanger were contained in a single vessel (Peterson, 1959). Protecting the reactor internals from the highly-corrosive fuel solution was supposed to have been achieved by coating the exposed surfaces with a thin layer of gold. While it was known that the problem of pinholes in the gold plating could not be completely eliminated (despite the use of multiple layers of gold), it was thought that the corrosion rate of the stainless steel under a pinhole in the plating would be tolerable (Peterson, 1959).

The first critical experiments with LAPRE I began on February 15, 1956 (Peterson, 1959). The reactor power was raised to a level of 20 kW and held there for five hours. Radioactivity was then detected in the steam line, and, shortly thereafter, criticality could not be maintained without dropping the temperature. The experiment was terminated with the fuel being transferred to an external tank. After nine days, the reactor was disassembled to determine the cause of the failure. Inspectors found that some of the gold plating on the heat exchanger tubes had been damaged during assembly of the reactor, thus allowing the hot fuel solution to come into direct contact with the stainless steel tubing. The fuel solution corroded several of the tubes, prompting failure. The corrosion rate observed was unexpectedly high relative to what had been predicted on the basis of laboratory tests (Peterson, 1959). Chemical attack was also noted at imperfections in the plating of the vessel and the boron poison can (Peterson, 1959).
Since the failure of LAPRE I was not due to the reactor itself, components were repaired or replaced as deemed necessary, and a second attempt at operating the reactor was made (Peterson, 1959). This second experiment was conducted on October 15, 1956. The reactor reached a power level of 160 kW, and held there for approximately two hours when radioactivity was detected in the feed water and steam systems, prompting a shutdown. Activity in the steam line rose rapidly, resulting in dose rates of 300 mR h^{-1} in the control room, probably because of gaseous activity released from the end of the steam line and drawn into the building ventilation system. Post-mortem inspection of the reactor determined that the failure was

again due to the heat exchanger tubes eaten away by the fuel solution. Since construction of LAPRE II was already underway at this time, further work with LAPRE I was abandoned (Peterson, 1959).

LAPRE II utilized a different fuel solution than LAPRE I. This new solution had a lower vapor pressure than the LAPRE I fuel (at the expense of less uranium solubility), and thus required a larger vessel to achieve a critical mass. LAPRE II was also designed to use bonded components, in hopes of solving the failures associated with the protective gold plating. Construction of LAPRE II began in February, 1956 (Clark, 1960). The reactor was located in an underground enclosure tank on the south side of the main laboratory building at TA-35. This arrangement proved prudent for providing the necessary radiation shielding. The design thermal power of the reactor was 800 kW. The primary purpose of the LAPRE II experiment was to demonstrate containment of phosphate fuels through suitable corrosion protection techniques.

Operation of LAPRE II began in February, 1959, and continued into May, 1959 (Clark, 1960). Full power operation was achieved on April 22, 1959. The fuel solution was kept in the reactor vessel at a temperature above 200 F for 46 days. A maximum temperature of 826 F was achieved. Like LAPRE I, LAPRE II experienced problems with volatile fission products leaking into the steam system. At full power, dose rates of several thousand R h^{-1} were present adjacent to the feed water heater (Clark, 1960). Though never determined for certain, the leakage was suspected to have occurred because of containment problems with the heat exchanger, ala LAMPRE I. Dismantlement of LAPRE II began on May 8, 1959, with the transfer of the fuel solution back to the storage tanks (Clark, 1960). The LAPRE program was terminated in 1960.

LAMPRE I

The following was adapted from "Early Reactors" by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983) except where otherwise noted:

The purpose of the LAMPRE program was to explore the issues associated with using plutonium fuel in fast breeder reactors using a reactor fueled with molten plutonium and cooled by molten sodium. While the original design of the LAMPRE I reactor called for a design power level of 20 MW, the researchers concluded that the knowledge base required to develop such a system was not yet sufficient. The design of LAMPRE I therefore underwent substantial changes, moving from a 20 megawatt system down to a 1 megawatt test reactor. The LAMPRE I core matrix was such that it could accommodate up to 199 separate fuel elements. Each element consisted of plutonium-iron fuel material in a tantalum thimble. The core matrix allowed several fuel element designs to be tested simultaneously.

The 1 megawatt design power for the LAMPRE I allowed it to be placed in an existing building at Ten Site (TA-35). A gas-fired 2-megawatt sodium cooling loop was also included to provide experience with high-temperature sodium-to-water heat exchangers. LAMPRE I achieved initial criticality in early 1961 and operated for several thousand hours thereafter. One of the problems encountered with it was tantalum fuel thimble corrosion from both the fuel and the coolant.

By mid 1963, LAMPRE I had achieved its intended purpose and was shut down. LAMPRE II, which was to be the 20 megawatt system first conceptualized for LAMPRE I, was never funded, with the AEC instead opting to pursue uranium-oxide-fueled reactors rather than plutonium-fueled systems. LAMPRE was in the Ten-Site cell adjacent to the one used for ^{140}La separation. It used molten plutonium contained within dozens of tantalum capsules, located within a sodium-cooled cylindrical core region about 40 cm high by 44 cm diameter. The LAMPRE fuel was transferred to Wing 9 at TA-3 (Wilson et al., 1979). LAMPRE experienced three separate fuel failures during operation; official reports say that these fuel failures did not cause any *operational* problems (Clark, 1962).

The Rover Program

In 1955, the United States initiated a program to develop a nuclear rocket engine to be used in defense systems and space exploration (Koenig, 1986). The plan was to carry large payloads into deep space, essentially by passing hydrogen through a very high temperature nuclear reactor, which would expand it and blast it out of the reactor at high velocity. Conducted with NASA, this program was called Project Rover. LANL was assigned the tasks of establishing the basic reactor design and leading the fuel development effort (Koenig, 1986). A series of test reactors were designed and built at LANL prior to being tested at the Nevada Test Site. These reactors were intended to first demonstrate proof of principle, then to establish and test the requisite design considerations. In 1962, Rover was the second largest program at LANL. The Rover program was cancelled in January, 1973.

The Rover reactors were developed by the Los Alamos Critical Experiments Group using the facilities at the Pajarito Site (TA-18). In general, each new Rover reactor was developed following the same basic progression. First, parametric studies were performed using the Honeycomb assembly to establish the appropriate dimensions. The design then proceeded to the mockup phase, where details for controls and internal structures were worked out. Finally, the completed reactors were assembled and inspected prior to being sent to NTS for testing. Adjustments were made if any deviations from specifications were noted during inspection (Paternoster and Kirk, 1991). Each Rover program reactor developed at LANL is listed in Table 5-1 below, along with the date the reactor was tested at NTS (Paxton, 1983).

Table 5-1. Rover Program reactors developed at Los Alamos

Reactor	Date(s) Tested at Nevada Test Site
Kiwi-A	July 1, 1959
Kiwi-A′	July 8, 1960
Kiwi-A3	October 19, 1960
Kiwi-B1A	December 7, 1961
Kiwi-B1B	September 1, 1962
Kiwi-B2A	test cancelled
Kiwi-B4A	November 30, 1962
Kiwi-B4D	May13, 1964
Kiwi-B4E	August 28 and September 11, 1964
Kiwi-TNT	January 13, 1965
Phoebus-1A	June 25, 1965
Phoebus-1B	June 26, 1968
Phoebus-2A	June 26, 1968
Pewee-1	November 21, 1968
Pewee-2	test cancelled
NF-1 (Nuclear Fuel Furnace)	June 29 and July 12, 21, and 27, 1972

Before shipment to NTS, the Kiwi-TNT reactor was operated at Pajarito Site beside the PARKA reactor (essentially a Phoebus 1 reactor set up as a critical assembly) to measure their interactions at various separating distances. A 1969 waste management plan indicated that the DP East facility processed new Rover fuel elements containing enriched uranium. Air from the exhaust systems handling radioactive materials was reportedly passed through HEPA filters. All four stacks from these systems were monitored but concentrations were below detectable levels (LANL, 1969).

UHTREX

The Ultra-High Temperature Reactor Experiment (UHTREX) involved constructing and operating a test reactor to advance the technology of high-temperature, graphite-moderated, gas-cooled reactors. The reactor was constructed in the late 1960s at Technical Area 52, and operated for approximately one year before being shut down in February, 1970 (Salazar and Elder, 1993). The UHTREX was cooled by helium gas in a system consisting of a primary and a secondary loop, and a single heat exchanger. Gas pressure in the two loops ranged from 475 psi to 545 psi, with the secondary loop kept at higher pressure than the primary in case leakage occurred within the main heat exchanger (LASL, 1967b). Under maximum conditions, the gas temperature at the core inlet was 1600 F, and the exit temperature was 2400 F (Salazar and Elder, 1993). The secondary loop coolant entered the heat exchanger at 200 F and exited at 1000 F (Salazar and Elder, 1993). A regenerative heat exchanger called the recuperator was used to re-

heat the primary coolant on its way back to the core. The recuperator also served to lower the primary coolant temperature from 2400 F to 1400 F prior to it reaching the main heat exchanger. The secondary loop rejected heat to the atmosphere in a building outside the main reactor building. This heat dump building housed finned tubes cooled by large fans. The reactor produced no power. The UHTREX utilized 93%-enriched uranium fuel in the form of small spheres of UO_2 coated with three layers of pyrolytic carbon and bound in a graphite matrix (LASL, 1967b). Fuel for the UHTREX was fabricated at the CMR Building (LASL, 1967b). The UHTREX was designed with a rotating core that allowed the reactor to be fueled while operating. The design thermal power for the UHTREX was three MW.

The UHTREX utilized a gas cleanup system on the primary coolant loop to remove fission products and outgases from the (unclad) fuel. The UHTREX reactor, primary cooling system, and the gas cleanup system were contained in a gas-tight secondary containment provided by the main reactor building (Salazar and Elder, 1993). The gas cleanup system consisted of metallic filters (to remove particulate matter), a copper oxide bed (to oxidize reducing agents), molecular sieve beds (to adsorb carbon dioxide and water), and water-cooled beds of activated carbon (to either trap volatile fission products or to delay fission gases to allow for radioactive decay) (LASL, 1967b). Delay times for the carbon bed were 1.2 h for krypton and 20 h for xenon. Under maximum conditions, 13 kW of decay heat were produced in the charcoal bed. Tritium produced in the primary coolant via the ^{3}He (n,p) ^{3}H reaction accumulated in the cleanup system in the copper oxide bed and in the molecular sieve beds. This tritium was eventually discharged up the 100 ft high main stack during regeneration of the sieve beds (LASL, 1967b). This process also resulted in the discharge of entrained fission gases (LASL, 1967b).

Air from the secondary containment, the fuel handling and gas sampling areas, and the change rooms and other such potentially contaminated areas passed through absolute (HEPA) and activated charcoal filters prior to being exhausted up the main stack (LASL, 1967b). Stack releases were monitored via a Tracerlab model MAP-1B/MGP-1A combination gas and particulate monitor (LASL, 1967b). The particulate monitor utilized a moving filter and a plastic scintillation detector. The gas monitor utilized a sodium-iodide detector. A removable charcoal filter was located between the particulate and gas monitors to allow for periodic assay of radioiodine concentrations via gamma-ray spectrometry. The stack monitor did not provide for "real-time" radioiodine monitoring. Air from the control room, offices, laboratories, equipment rooms, and other such "clean" areas was exhausted through rooftop vents. The UHTREX facility was designed so that air flowed from clean areas to potentially contaminated areas.

Spent fuel from the UHTREX was loaded into casks and transported by truck to Wing 9 of the CMR Building, where it was evaluated utilizing the hot cell facilities available there (LASL, 1967b). Liquid

radioactive wastes were carried by contaminated waste lines to the TA-50 treatment facility. Decontamination and Decontamination (D&D) of the UHTREX site and facilities began in the late 1980s. All radioactively-contaminated solid waste was buried at the laboratory's central waste disposal facility (TA-54) (Salazar and Elder, 1993).

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Chapter 6: Accelerator Operations at LANL

During World War II, accelerators were used to determine the critical mass for each proposed atomic bomb design. Two Van de Graaff accelerators were acquired from the University of Wisconsin, a Cockcroft-Walton accelerator was "borrowed" from the University of Illinois, and a cyclotron was purchased from Harvard (Hoddeson et al., 1993).

These machines supplied neutrons for studying the neutron interactions involved in an explosive fission chain reaction. Such study was important because these interactions had not been studied at all of the neutron energies relevant to a nuclear explosion; no moderation, or slowing down, of fast neutrons emitted from the explosion occurs. This is contrary to previous neutron studies from early graphite reactors, where moderation in the core occurred. The accelerators also supported the effort to find a way of preventing a "fizzle," or predetonation, in the gun-assembled plutonium bomb. A circular electron accelerator called a betatron was later procured to obtain sequences of images of spheres of mock fission fuel as they were being imploded by surrounding high explosives (Reichelt, 1993).

During the postwar years, LANL's emphasis was on building a foundation of basic scientific research with weapons applications. Three wartime accelerators were purchased and retained by the government– the Short Tank, the Cockroft-Walton, and the cyclotron. The Long Tank was returned to the University of Wisconsin, but was replaced by a high-energy Van de Graaff accelerator with a vertical configuration. The neutrons from that device and the Cockroft-Walton were used to study neutron interactions relevant to nuclear fusion. The old Harvard cyclotron was upgraded into a variable-energy cyclotron that was used to study the angular distributions of accelerated particles after they scattered off the nuclear of various target elements (Reichelt, 1993).

Two electron linear accelerators (linacs) were later built to provide radiographs of the implosion process, in work that led to the 1963 construction of PHERMEX (pulsed high-energy radiographic machine emitting x rays). PHERMEX generates x rays by accelerating an electron beam onto a tungsten target, and the x-ray bursts are sent through model weapons at a remote blasting site to provide three-dimensional images of imploding spheres (Reichelt, 1993).

Relatively small accelerators that have been used at Los Alamos include:

- W Building at TA-1 housed a Van de Graaff accelerator. Building W had 2 high-voltage electrostatic generators used to produce variable energy neutrons for cross-section measurements.

Protons were accelerated and would strike a target (usually lithium), at which point, neutrons and X-rays would be produced. Hazards from neutrons and X- rays were also generated.

- TA-3 Building 16 housed a Van de Graaff accelerator (a.k.a. SM-16). On May 24, 1977, the Van De Graaff accelerator released up to 800 Ci of tritium (Alquist and Ganderson, 1970, Alquist et al., 1977).

Accelerator Operations at Technical Area 53

TA-53 houses the largest accelerator facility at LANL. Following is a list of acronyms that are used in the discussion of TA-53:

LAMPF = Los Alamos Meson Physics Facility; WNR = Weapons Neutron Research Facility; LANSCE = Los Alamos Neutron Science Center; PSR = Proton Storage Ring; MeV = Million Electron Volt (energy unit); MAP = Mixed Activation Products

The primary facility at TA-53 is a large accelerator complex originally called the Los Alamos Meson Physics Facility (LAMPF). The original sections of LAMPF were later renamed the Clinton P. Anderson Meson Physics Facility. LAMPF is a nominal 800 MeV, 1-milliampere intensity proton linear accelerator. Construction on LAMPF began in 1968. On June 12, 1972, LAMPF first obtained a full energy beam. Originally constructed to study sub-atomic particles, LAMPF today serves as an accelerator generating intense pulses of neutrons (by sending the protons into targets of high atomic number such as uranium) for scattering research at the WNR and LANSCE facilities. The PSR is used to accumulate protons and provide a short duration pulse of protons for targeting onto uranium and other high atomic number targets for neutron production at WNR.

Today, the complex is called the Los Alamos Neutron Science Center, and includes the linear proton accelerator, the Manuel Lujan Jr. Neutron Scattering Center, and a medical isotope production facility. In addition, the Accelerator Production of Tritium Project Office, including the Low-Energy Demonstration Accelerator, and R&D activities in accelerator technology and high-power microwaves, are located at TA-53.

LANSCE Release Summary

LANSCE airborne radionuclide releases consist of short-lived radioactive materials that have been activated from air. These radioactive materials are composed of particulates from activated dust in air and gaseous activation products from air constituent gases. Another source of LANSCE radionuclide

releases is the cooling water used for cooling accelerator components. Non-radioactive releases at accelerators include solvents, which are used in large volumes for cleaning vacuum components.

LANL documents refer to the mix of short-lived materials as Mixed Activation Products (MAP). Some other acronyms seen in documents are "G/MAP" for Gaseous Mixed Activation Products and "P/VAP," which stands for Particulate Various Activation Products. These radioactive materials are produced when the proton beam from LAMPF is sent through air, or when a fraction of the proton beam is lost through interactions with accelerator components (such as targets). These interactions generate neutrons, which subsequently activate the air gases and the dust in air.

Radionuclide releases from LANSCE occur in two ways: 1) from the four stacks located in the facility, which are monitored both for particulates with filters and for gases with Kanne chambers; and 2) via unintentional pathways of diffuse release via doors and other exit points. For some periods of time, these combined emissions have been the source of the highest priority releases to the environment. The radionuclide releases reported at LANSCE are among the highest of all DOE operations nation-wide. The amount of radioactivity released from LANSCE increases proportionally as the power levels and beam-on time increase. Principal gaseous radionuclides constituents released were ^{11}C (20 min), ^{13}N (10 min), ^{15}O (2 min). A trace amount of ^{41}Ar (1.8 h) was also released. The particulate releases are too numerous to mention, and are only present in trace levels, since they consist of activation products from dust in air or disintegrated target material.

Cooling water that services accelerator components, including targets, also becomes radioactive, and also accumulates corrosion products from the target and magnet systems. This water has been released by the site after decay in concrete walled cooling water ponds that have bentonite clay on the bottom. The cooling water is held until no short-lived radionuclides are observed in the water; after confirmation measurements, the cooling water from these ponds is then released, and becomes surface water.

Prioritization of LANSCE Releases

The releases from LANSCE have been cataloged in detail by the LAHDRA team in two calculations (O'Brien and Burmeister, 2004a, 2004b). Results of the prioritization assessment for airborne radionuclides are presented in Chapter 17. The calculation of Priority Indices (PI) involves dividing the reported annual release by the maximum effluent concentration from 10 CFR Part 20. The result represents the volume of air required to dilute the releases to the maximum permitted value, and therefore permits comparisons for varying amounts of radioactive material from year to year based on the total quantities of air required to dilute the effluent. The maximum effluent concentration value used for MAP

comes from the International Atomic Energy Agency (IAEA, 1979) and was 2.0×10^{-7} μCi mL^{-1}. The prioritization shows that LAMPF dominates site releases to air since the mid-1970s.

Detailed LANSCE Release Data

The LAHDRA project team has spent many hours finding and reviewing LANSCE records. The project team has identified two key document resource centers within TA-53 that provide substantial quantities of historical effluent monitoring data for LANSCE. Those records cover operations from the early 1970s to the present. The locations are:

- Building 3, Room 3R-4 (TA-53-3) - Radiological records that contain mostly exhaust stack and water monitoring data for radionuclides.

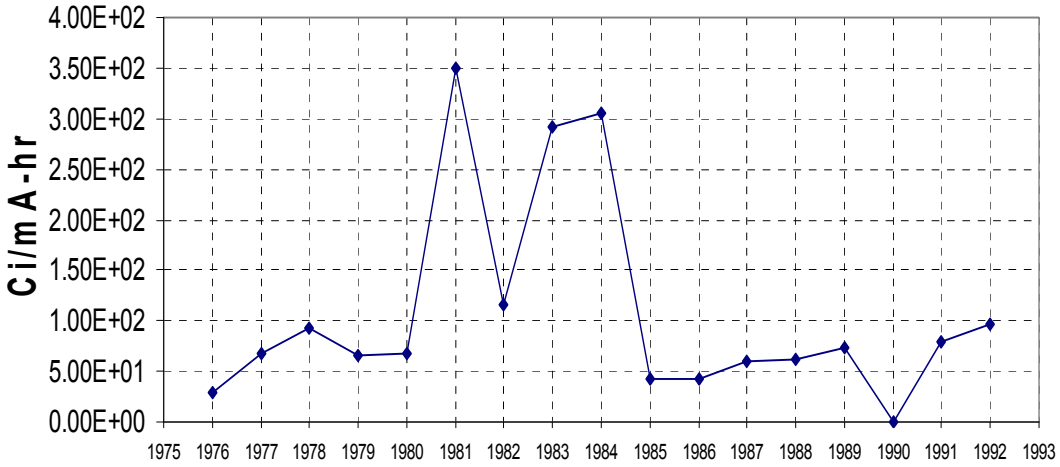
- Another location for useful records is the operations group in Building 53. Management staff at the accelerator facility generally opted to retain large portions of their records for historical and operational purposes, and has stored these records on-site at TA-53.

Monthly and annual air emission reports from 1976 to the present have been located by the LAHDRA team. These reports also present backup information pertaining to how LANL staff performed and collected stack monitoring data and calculated air releases. In related reports, methods for calibrating Kanne "flow-through" ionization chambers and stack measurements are presented.

Probably the most appropriate method of estimating releases is to use the accelerator operation logs to obtain the milliampere-hours (mA-h) of beam operation. Periods of accelerator operation are called "cycles," and each cycle is given a sequence number. These data included operations during cycles 3 through 61. Data for cycle 1 and 2 were not found. Data for cycles above 61 are available, but were not captured. In the LANSCE Effluents spreadsheet, beam current was multiplied by beam-on time to calculate mA-hrs for the beam. These values were summed to yield annual values of beam time in mA-h (see Table 6-1). Curies per mA-h are plotted in Fig. 6-1.

Table 6-1. Compiled annual beam current data for LANSCE

Year	mA-h (from log books)	Annual Activity in Curies	Curies per mA-h
1974		1.00E-08	
1975		1.00E-08	
1976	202.66	6.06E+03	2.99E+01
1977	702.27	4.79E+04	6.82E+01
1978	1,259.80	1.17E+05	9.29E+01
1979	1,834.57	1.19E+05	6.49E+01
1980	2,180.00	1.46E+05	6.70E+01
1981	1,010.79	3.53E+05	3.49E+02
1982	2,151.52	2.51E+05	1.17E+02
1983	1,593.71	4.64E+05	2.91E+02
1984	2,420.37	7.37E+05	3.04E+02
1985	3,004.61	1.26E+05	4.19E+01
1986	2,600.06	1.12E+05	4.31E+01
1987	2,534.84	1.50E+05	5.92E+01
1988	1,929.32	1.21E+05	6.27E+01
1989	2,128.43	1.56E+05	7.33E+01
1990	1,966.90	5.00E+02	2.54E-01
1991	721.56	5.75E+04	7.97E+01
1992	744.83	7.19E+04	9.65E+01
1993		2.11E+02	
1994		5.04E+04	
1995		4.37E+04	
1996		1.14E+04	



Fig, 6-1. Ci/mA-h for LANSCE operations 1975-1993

There were some columns in the beam operation logs that were not used in these informal calculations, since it was not known how to apply them. One column was for "Duty Factor," and two contained additional beam information: "Beam Current 2" and "Beam Hours 2." From verbal conversations with LANL employees LAHDRA staff found that the "Beam Current 2" and "Beam Hours 2" were used only when the beam was run at one current for a certain amount of time and then was run for a second amount of time at a different beam current. Since there were few instances of this information being supplied, it was ignored for this informal calculation. "Duty Factor" was explained as having something to do with the pulsed nature of the output used sometimes during the operation. Since it was not know how to apply a correction factor for "Duty Factor," this column also was not used.

In addition to point release estimates (i.e., exhaust stack releases) LANL began estimating non-point (diffuse) emissions in its annual release and dose estimates. Documents were found for 1993, 1995, 1996, and 1997. The estimates of diffuse releases were 1,418 Ci, 716 Ci, 221 Ci, and 866 Ci for the years listed, respectively. These quantities are approximately less than 10% of the annual airborne release values as shown in Table 6-1. The vast majority of these releases were estimated to be ^{11}C.

Documentation regarding sampling indicates that short-lived activation gases were not reported at LAMPF for the 1974 to 1978 time frame (LANL, 1974-1978). One of the documents abstracted (Cochran, 1970) refers to a letter to the AEC concerning LAMPF airborne emission in 1970, thus indicating that limited operations may also have occurred prior to 1972.

The TA-53 data suggest that there are at least four stacks for which data are available. These stack designations include: FE-3 (North Stack, also called main stack in 1981); FE-4 (South Stack); FE-16; and, FE-2. The FE-3 fan serviced the main accelerator tunnel, and was terminated in 1980. The FE-4 fan was added in 1977. FE-3 and FE-4 have reported emissions primarily of short-lived air activation products such as: ^{11}C, ^{13}N, ^{15}O, ^{41}Ar, and ^{7}Be. FE-2 services the WNR, and was added in 1981. FE-16 services TA-53-1 D-wing, with releases reported for other longer-lived radionuclides such as ^{7}Be.

Cooling water was released to floor drains that fed two 2,500-gal carbon steel tanks. These tanks were discharged to the cooling water ponds (LANL, 1981). The magnitude of releases at LANSCE resulted in continuing studies to estimate the off-site impact, such as 1987 study that documented the releases and modeling of the releases for 1985 (Bowen et al., 1987). Laboratory measurements have been found for lagoon and cooling pond waters, and for long-lived activity that can be collected on filtering media. The short-lived MAP was assessed with on-line monitoring and through TLDs located at various locations.

Repos. No. 1556 discusses the diffuse releases from LAMPF for 1990, which were 0.21 Ci, just a small fraction of the 120,000 Ci of short-lived gases that were reported (Hecker, 1991). The diffuse emissions were comprised of longer lived nuclides (since the diffuse emissions are completely unfiltered), and a comparison of curies alone might be misleading, but the magnitude of diffuse emissions is clearly less significant than that of the primary release points.

The LANL assessment of radioactive release impact from TA-53 has changed in many ways over the years. Prior to 1991, LANL assessed the releases by taking credit for estimated occupancy and the inherent shielding provided by residences. In 1992, however, LANL was told by the USEPA that no credit should be taken for shielding and residency time factors (Brown et al., 1992). This instruction resulted in a change of methodology for projecting impacts from the releases, and thus care should be taken when comparing LANL assessments for different periods.

Conclusions Regarding LANSCE Operations

LANSCE is an important major scientific system at LANL; its operation is important both to LANL scientists and researchers and to visiting organizations. Since its inception, LANSCE has been one of the major contributors to airborne releases to the environment. Fortunately, the radionuclides released are short-lived gases or trace amounts of particulates from diffuse emissions. Future projects that attempt to create an accurate source term for LANSCE should concentrate on applying the additional beam time corrections, applying the duty factor corrections, locating early operation info (cycle 1 and 2), and ensuring that the curie quantities in the OSR Database are complete and accurate so that the Ci/mA-h can be calculated accurately for LANSCE.

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Chapter 7: Tritium Processing at LANL and a Screening Assessment of Public Exposures

The benefits of incorporating tritium into nuclear weapons design was recognized early in the Manhattan Project. Facilities and processes for tritium production were a topic of discussion at LANL at least as early as 1944 (Allison, 1944). By this time, tritium production efforts had already begun at the X-10 site (now the Oak Ridge National Laboratory), and there were discussions about large-scale tritium production taking place at Hanford. As of late 1945, LANL had installed equipment for purifying and assaying tritium. LANL's CMR Division began using this equipment to supply tritium to groups within P Division and M Division in early 1946. A tritium collection system was being installed in the laboratories of Group P-4 as of March, 1946 (LASL, 1946). It is unclear where these operations took place, but small quantities of tritium are reported to have been used in Buildings U, W, and Z in the Original Technical Area (TA-1). As LANL operations matured, significant quantities of tritium were released to the atmosphere from facilities in TAs 3, 21, 33, 35, and 41. In addition, tritium was used in some firing site (dynamic testing) activities (at TA-15, for example).

Tritium Facilities at TA-3

The three facilities responsible for the majority of atmospheric tritium releases from TA-3 were the Cryogenics Laboratory (Building SM-34), the Ion Beam Facility (Building SM-16), and the CMR Building (Building SM-29). Both the Cryogenics Laboratory and the IBF used tritium gas generated from uranium tritide[a] beds.

The LANL Cryogenics Laboratory opened in 1955, and reportedly released 28,000 Ci of tritium from 1976 to 1985 (Morgenstern and Hueske, 1995). The Ion Beam Facility (IBF), which housed two Van de Graaff accelerators, began operating in 1951 (Loomis et al., 2005). The accelerators produced neutrons by bombarding tritium gas targets with charged particles. Atmospheric tritium releases for the IBF are reported to have been 14,000 Ci from the 1960s through 1992 (Morgenstern and Hueske, 1995). Morgenstern and Hueske (1995) also report a release of 11,000 Ci of tritium from the CMR Building from the time its operations began in 1953. The reported releases for these three facilities total 53,000 Ci.

[a] A tritide is a hydride (a binary compound formed by the union of hydrogen and one other element) in which hydrogen is in the form of its ^{3}H isotope.

Tritium Facilities at TA-21

TA-21 has housed the LANL Tritium Handling Facility (THF) and the Tritium Systems Test Assembly (TSTA), as well as earlier tritium operations. The THF was also known as the Tritium Salt Facility (TSF). It was expanded in 1984, and subsequently became known as the Tritium Science Fabrication Facility (TSFF). The THF was activated December 5, 1974 as a replacement for obsolete tritide salt processing facilities at TA-35. It was located at DP East Site in Building TA-21-209. The THF consisted of a large dry box system and a gas purification system. Its purpose was to house processes involving metal tritides, and, specifically, tritium-bearing lithium salts. As of December 12, 1979 the THF had reportedly processed 3.8 million curies of tritium, and had released 704.5 Ci to the atmosphere via its local stack (Nasise, 1980).

TSTA was a facility for the integrated testing, in full scale, of the processes and safety systems required for the reprocessing and recycling of plasma exhaust gas from a tokamak fusion reactor. The primary material handled was deuterium-tritium (DT) gas. Tritium was first introduced at TSTA on June 25, 1984 (Jalbert, 1985).

Tritium appears to have been in use at DP West since at least the early 1950s. In 1952, J. B. Webber of LANL described sampling of effluent streams for tritium oxide from a beaker of tritiated water placed in various locations in DP West Room 326 (Webber, 1952). By 1971, a tritium stack monitor had been installed for DP West Room 513 (Johnson, 1971).

Tritium Facilities at TA-33

TA-33 was established in 1947 primarily as a test site for atomic bomb initiators (Garcia et al., 2004). Dynamic testing activities took place there involving polonium and other materials. Shots were fired in underground chambers and at the surface. Large guns were used to fire test projectiles into berms. In the early 1950s, facilities were designed and built at TA-33 for processing tritium gas (Coffin, 1971). The high pressure tritium gas facilities were housed in Building HP-86 and operated there until late 1990 (Garcia et al., 2004). In addition to its function as a high pressure tritium pumping station, Building HP-86 also had laboratory areas for testing tritium gas systems and for studying material compatibility (Tuggle, 1983). Building HP-86 had a 75-foot stack as of late 1962, though apparently the stack height had increased from its original design (Deinken, 1962).

On an activity basis, Building HP-86 is believed to be the largest source of atmospheric releases of tritium at LANL. Coffin (1971) stated that routine releases to the atmosphere were 2,000 to 6,000 Ci annually, and that 60,000 Ci of gas had been released in ten separate incidents dating back 15 years. These

accidental releases were in addition to routine releases associated with the evacuation of lines and vessels containing tritium gas and leakage from the gas system overall. The gas system consisted of a process system and a filling system, with the former used to mix and prepare gases for introduction into the latter (Holmes, 1965). The filling system was used to fill a desired container with tritium gas at a desired pressure. Coffin (1971) estimated the contributions from routine and accidental releases to the total atmospheric source term to be approximately equal. The LAHDRA document collection contains numerous references documenting accidental releases of large quantities of tritium gas at TA-33.

Tritium Facilities at TA-35

The original tritium salt facility was located in the basement of Building 2 at TA-35. It was constructed in 1953 (Harper and Garde, 1981) and was in use until 1974, when the tritium salt operations moved to DP East Site. The TA-35 tritium salt facility was decommissioned in 1979. The facility was used to handle lithium tritide salts containing kilocurie quantities of tritium, and consisted of two glovebox lines, associated equipment, and its own exhaust stack (Harper and Garde, 1981). Tritium operations began in 1955 (Storm, 1972), and ended in 1979 with the decommissioning of the facility. Tritium releases from the TA-35-2 facility did not end when operations were relocated to DP East Site. Releases continued to be monitored and reported through the decommissioning process.

The lithium tritide salts were received from Mound Laboratory in a powdered form and were processed and packaged at TA-35 for transfer to Group W-1 (Storm, 1972). As of 1972, the frequency of the operation was six to 24 weeks per year. Water reacting with the salt compound resulted in the release of tritium. This condition was exacerbated by the high moisture content of the glovebox cover gas and the use of water to clean some of the process equipment (Storm, 1972). The fact the tritium was released through a water-salt reaction prompted Ellery Storm of LANL to conclude it was probably released in the oxide form.

Tritium Facilities at TA-41

TA-41 was constructed in the early 1950s for weapons development activities (LANL, 1988). It was built at the bottom of Los Alamos Canyon, approximately 300 feet below the mesa tops. A central exhaust system and stack were added in 1962. Prior to that time, process effluents were ventilated by local stacks and exhausts serving individual laboratories. TA-41 consists of a number of structures, including an underground vault for storing explosives and special nuclear material. The vault, designated Building W-1, is a reinforced concrete structure constructed by tunneling into the north wall of Los Alamos Canyon.

It was built in May, 1949 (LANL, 1991). Materials stored in the W-1 vault included pressure vessels containing tritium gas.

It is unclear when tritium operations first began at TA-41. LANL's 1973 estimates of atmospheric tritium releases included estimates for TA-41 dating back to 1967 (LASL, 1973). In 1976, LANL was evaluating locating a new tritium handling facility at TA-41 (Barnes, 1976) to replace operations at the HP-86 facility at TA-33. It is not clear when these activities began, but it appears they continued until approximately the early 1990s. As of 1983, one of the primary activities at TA-41 was building and testing equipment and systems for storing and transferring high pressure gases, including tritium (Tuggle, 1983). In 1992, LANL determined that the cost associated with upgrading the TA-41 facilities to allow for resuming programmatic tritium operations involving quantities greater than 1,000 Ci was not justified (Erickson, 1993). Those operations were to be transferred to the Weapons Engineering Tritium Facility at TA-16.

TA-41 was also used for plutonium operations, dating back to at least 1957 (Buckland, 1957), and uranium operations. As of 1983, plutonium and uranium were handled only in sealed containers. Experiments with the containers were conducted inside double containment (Tuggle, 1983).

Other Tritium Facilities

As of 2001, the largest tritium inventory at LANL was held at the Weapons Engineering Tritium Facility (WETF) at TA-16. Originally constructed as a replacement for the tritium gas facilities at TA-33 (LANL, 1990), the WETF houses research and development activities that support nuclear weapons programs and inertial confinement fusion (DNFSB, 2001). Consolidation efforts were underway at the time to relocate all of LANL's tritium processing operations to the WETF. The WETF is a more modern facility than its predecessors, and its tritium releases to the atmosphere are relatively small. Other LANL facilities that contribute to atmospheric tritium releases are waste treatment operations at TA-50, and operations involving tritium-contaminated weapons components at TA-55. There have also been limited tritium operations conducted at a gas boosting test facility housed at TA-9 (Tuggle, 1983). With respect to environmental levels, a significant source of atmospheric releases of tritium oxide has been LANL's central waste disposal facility at TA-54. Buried tritium-bearing waste materials result in atmospheric releases of tritiated water vapor via evaporation from the soil. These releases are evident in the measurements from the local ambient air monitoring stations.

Atmospheric Effluent Data for Tritium

LANL did not begin monitoring tritium stack releases until 1971. In 1973, LANL prepared estimates of atmospheric releases for 1967 through 1970 based on accountability data (LASL, 1973). There are no formal estimates of total tritium releases prior to 1967, though the LAHDRA document collection contains effluent monitoring and other tritium release data for some tritium facilities prior to 1967. How complete a picture this information might represent with regard to LANL's total atmospheric tritium releases for the pre-1967 period, though, is currently unknown.

Table 7-1 shows annual releases of tritium to the atmospheric reported by LANL for the period 1967 through 1996. The releases are given in microcuries (μCi) for Technical Areas 3, 15, 21, 33, 35, and 41. The data for 1967 – 1970 are from the estimates LANL prepared from accountability data (LASL 1973). For 1971 forward the data came from LANL's environmental surveillance reports, with the exception of the TA-15 data, which still came from the accountability data for 1971 and 1972. After 1972 all of the reported releases came from the annual environmental surveillance reports.

All of the values in Table 7-1 are as-reported by LANL. No adjustments have been applied by the LAHDRA team and no independent verification has been performed. Entries of "--" in the table mean no data were reported by LANL for that TA for that period.

Table 16-1 of this report presents a partial chronology of accidents, incidents, and important events that occurred at LANL over its history. Table 7-2 shows events from Table 16-1 that involved atmospheric releases of tritium prior to 1967, when LANL began preparing release estimates. The examples shown in Table 7-2 are events for which a quantitative estimate of the tritium released can be found in the associated documentation. There are other known incidents involving atmospheric releases of tritium in the pre-1967 era for which release estimates are not given.

Comparing the data in Table 7-2 with that from Table 7-1, one can infer that large releases of tritium gas from the HP-86 facility at TA-33 were not unusual and thus the total given for TA-33 may be significantly understated. The same can be said for tritium releases from TA-3. In addition, Morgenstern and Hueske (1995) assert a total release for TA-3 of 5.3×10^{10} μCi, dating back to 1953, when CMR Building began operations. This is nearly twice the total activity shown for TA-3 in Table 7-1.

Table 7-1. Airborne tritium release data reported by LANL for selected TAs (μCi)

Year	TA-3	TA-15	TA-21	TA-33	TA-35	TA-41	Total
1967	8.72E+08	3.60E+09	--	1.13E+10	--	1.22E+10	2.79E+10
1968	1.04E+10	4.60E+09	2.33E+07	5.51E+09	--	1.58E+10	3.63E+10
1969	1.72E+08	4.51E+09	2.50E+06	2.01E+10	--	9.76E+09	3.45E+10
1970	--	1.10E+10	--	6.70E+08	2.50E+10	4.38E+08	3.71E+10
1971	8.90E+07	2.66E+09	5.00E+06	4.10E+09	3.13E+09	3.20E+08	1.03E+10
1972	4.80E+07	1.80E+09	--	2.90E+09	2.50E+09	1.10E+08	7.35E+09
1973	--	9.30E+08	4.00E+06	3.90E+09	1.20E+09	5.90E+07	6.09E+09
1974	--	1.71E+08	--	5.92E+09	1.40E+09	--	7.49E+09
1975	2.20E+07	--	3.06E+08	3.48E+09	2.39E+09	--	6.20E+09
1976	--	--	9.50E+07	1.35E+09	1.66E+09	--	3.10E+09
1977	4.00E+08	--	1.33E+08	3.14E+10	7.86E+08	--	3.27E+10
1978	1.00E+08	--	7.20E+07	1.78E+10	6.76E+08	--	1.86E+10
1979	3.01E+09	--	9.50E+07	1.05E+10	1.30E+09	1.43E+08	1.50E+10
1980	4.55E+06	--	1.06E+08	6.97E+09	2.50E+07	4.14E+08	7.51E+09
1981	8.99E+08	--	1.08E+08	6.09E+09	--	1.26E+08	7.22E+09
1982	1.94E+09	--	1.69E+08	1.36E+10	--	1.30E+08	1.58E+10
1983	2.46E+09	--	--	4.41E+09	6.00E+06	9.74E+08	7.85E+09
1984	1.79E+09	--	8.02E+08	7.11E+09	2.06E+08	4.78E+09	1.47E+10
1985	2.12E+09	--	3.67E+08	4.87E+09	5.30E+06	1.27E+09	8.63E+09
1986	1.23E+09	--	4.48E+08	6.66E+09	4.80E+07	1.32E+09	9.70E+09
1987	8.51E+08	--	5.96E+08	1.00E+09	1.55E+08	4.70E+08	3.07E+09
1988	3.90E+08	--	5.28E+08	7.96E+09	1.18E+08	1.73E+09	1.07E+10
1989	2.91E+08	--	4.52E+08	1.77E+09	1.80E+07	1.16E+10	1.41E+10
1990	4.96E+08	--	4.39E+08	8.54E+08	5.00E+04	4.44E+09	6.23E+09
1991	2.05E+08	--	3.23E+08	2.54E+08	--	3.84E+09	4.62E+09
1992	1.15E+08	--	4.29E+08	3.18E+08	1.00E+05	2.92E+08	1.15E+09
1993	7.63E+07	--	4.26E+08	3.50E+08	--	4.83E+08	1.34E+09
1994	5.38E+07	--	3.32E+08	4.56E+08	--	1.72E+08	1.01E+09
1995	2.25E+06	--	7.12E+08	1.09E+08	--	7.85E+07	9.02E+08
1996	--	--	3.92E+08	5.00E+07	--	1.10E+08	5.52E+08
Total	2.80E+10	2.93E+10	7.37E+09	1.82E+11	4.06E+10	7.10E+10	3.58E+11

Table 7-2. Examples of pre-1967 atmospheric tritium release events found in the LAHDRA document collection

Date	Location	Tritium Released (µCi)
7/25/1958	TA-33	~1.3×10^{10}
3/17/1959	TA-3	3.1×10^{8}
3/9/1962	TA-41	7.6×10^{9}
10/3/1964	TA-3	2.0×10^{8}
2/16/1965	TA-33	5.0×10^{9}
6/9/1966	TA-3	7.8×10^{8}

To ensure a conservative approach to screening, and to account for the fact the tritium release data in Table 7-1 are not complete, the maximum annual atmospheric tritium releases reported for each of the selected TAs were compiled. These are shown in Table 7-3.

Table 7-3. Maximum reported airborne tritium releases from LANL

Technical Area	Maximum Release (µCi)	Year
3	1.04×10^{10}	1968
15	1.10×10^{10}	1970
21	8.02×10^{8}	1984
33	3.14×10^{10}	1977
35	2.50×10^{10}	1970
41	1.58×10^{10}	1968

For screening purposes, the maximum values should, at a minimum, be representative of LANL's atmospheric tritium releases for the period 1967 forward, if not bounding in the case of the earlier data derived from accountability data. For the principal contributors to atmospheric tritium releases, all but two of the maximum values were from the period prior to the onset of stack monitoring; that is, they were derived from accountability data. Such estimates are typically conservative with respect to the true release; again, none of the data used in this evaluation have been independently verified.

Chemical Forms of Tritium

One of the most important factors to consider when evaluating atmospheric releases of tritium for potential health risks is the chemical composition of the release. Specifically, it is important to know if the release was in the form of tritium gas, or if it was partially or completely in the form of tritium oxide. Tritium is a radioactive isotope of hydrogen. Tritium gas refers to tritium in the form of diatomic HT or T_2 gas, where T is used in place of H to differentiate between atoms of tritium and protium (normal

hydrogen). Tritium oxide refers to molecules of water (normally H_2O), in which a tritium atom has been substituted for one or both of the hydrogen atoms to form HTO or T_2O. The difference between tritium gas and tritium oxide is enormous in terms of radiation dose to a human receiver. If inhaled, tritium gas is not incorporated into the body to any appreciable degree, and the only dose consequence is the direct exposure to lung tissue. Tritium oxide, in contrast, behaves similar to water, and is readily incorporated into body tissues. In terms of radiation dose per unit intake, the dose from tritium oxide exceeds that from tritium gas by four orders of magnitude (ICRP, 1996). Dose from tritium gas, therefore, is typically negligible. There is no external dose consequence from tritium in either form, but intakes of tritium oxide can result from absorption through exposed skin in addition to inhalation.

Given its application in the weapons program and accelerator operations, tritium at LANL has primarily been used in its tritium gas form. There are some circumstances, however, in which an assumption of the oxide form is appropriate, at least for initial screening purposes. In addition, as of the late 1970s, LANL installed catalytic converters on its tritium stacks to convert the gaseous effluent to oxide. This conversion allows the tritium to be efficiently collected on molecular sieves, and thus significantly reduces the overall release. However, anything not captured by the sieve system takes the oxide form. This system for reducing tritium emissions was described in 1973 by R. R. Dube of LANL's GMX-4 group and his colleagues (Dube et al., 1973).

In addition to gas and oxide, other chemical forms of tritium are possible. With respect to tritium operations at LANL, tritium could historically be found in the form of metal (uranium) tritides or lithium tritide salts. Unlike gases, any atmospheric emissions of these materials would be in particulate form, and absorption and retention in the body would depend on the characteristic biokinetic behavior for the specific tritide compound. No information has been noted in the LAHDRA document collection regarding the atmospheric release of tritide compounds, and it is believed to be unlikely that tritides would have been a significant component of LANL's atmospheric tritium releases. From a radiation dose perspective, tritides represent more dose per unit activity than tritium oxide because they are retained in the body longer. In the case of tritide particulates, because of the longer retention characteristics, the dose per unit intake exceeds that for tritium oxide by a factor of 14 (ICRP, 1996).

Screening LANL's Atmospheric Tritium Releases for Potential Health Risks

The NCRP Report No. 123 (NCRP, 1996) screening method for radionuclide releases to the environment was used to evaluate atmospheric tritium releases from LANL in terms of their potential risk to local residents. The source term used was the maximum release reported for each of the six TAs that

represented the largest contributors to LANL's atmospheric tritium releases. These maximum values, shown in Table 7-3, were converted to units of becquerels for input into the NCRP Report No. 123 screening models. The converted values are shown in Table 7-4.

Table 7-4. Maximum reported airborne tritium releases from LANL

Technical Area	Maximum Release (Bq)	Year
3	$3.84\times10^{+14}$	1968
15	$4.07\times10^{+14}$	1970
21	$2.97\times10^{+13}$	1984
33	$1.16\times10^{+15}$	1977
35	$9.25\times10^{+14}$	1970
41	$5.84\times10^{+14}$	1968

The values in Table 7-4 reflect total amounts of tritium released. To ensure a meaningful screening result, they were re-stated in terms of the corresponding tritium oxide activity for each total value. An upper bound for the fraction of a tritium gas source that has converted to an oxide form is 1% (Pan and Rigdon, 1996, Mishima and Steele, 2002). The small amount of oxide is formed by interactions between residual air in the storage vessel and beta radiation from the tritium. Following a release of tritium gas, additional oxidation occurs slowly, resulting from either additional radiolytic reactions with air (in the case of high activity concentrations), or from photochemical reactions with ultraviolet light. These secondary oxidation mechanisms result in conversion rates ranging from approximately 1% per hour, in the case of high activity concentrations, to falling off to less than 1% per day as the gas diffuses following release (Mishima and Steele, 2002). Tritium gas does not react strongly with water vapor. If there is an ignition, explosion, or similar event involving tritium gas, then an assumption of complete (100%) oxidation is appropriate.

Based on what was known about the processes associated with the maximum atmospheric tritium releases in Table 7-4, conservative assumptions were applied to determine the chemical form of the tritium to be assumed for screening. These are documented in Table 7-5, with tritium oxide being designated HTO.

Table 7-5. Activity and chemical forms of tritium used for screening

Technical Area	Maximum Release (Bq)	Assumed Chemical Form and Basis	Maximum Release as Oxide (Bq)
3	$3.84\times10^{+14}$	1% HTO: principal sources were tritium gas.	$3.84\times10^{+12}$
15	$4.07\times10^{+14}$	100% HTO: assume tritium was expended in detonation events.	$4.07\times10^{+14}$
21	$2.97\times10^{+13}$	100% HTO: assumed releases were the result of water reactions with tritium-bearing salts resulting in an oxide form.	$2.97\times10^{+13}$
33	$1.16\times10^{+15}$	1% HTO: HP-86 was a tritium gas facility.	$1.16\times10^{+13}$
35	$9.25\times10^{+14}$	100% HTO: assumed releases were the result of water reactions with tritium-bearing salts resulting in an oxide form.	$9.25\times10^{+14}$
41	$5.84\times10^{+14}$	1% HTO: operations were similar to those at TA-33.	$5.84\times10^{+12}$
Total	$3.49\times10^{+15}$	--	$1.38\times10^{+15}$

For screening, the maximum release values in Table 7-5 were considered both on an individual and on an aggregate basis (the six values added). Summing the maximum values, which occurred in different calendar years, is believed to provide a source term that is at worst representative of any specific year and is likely bounding. Again, the maximum release data for TAs 3, 15, 35, and 41 are based on LANL's examination of accountability records, and such assessments are typically conservative with respect to actual releases. On an aggregate basis, the source term in Table 7-5 represents $3.49\times10^{+15}$ Bq (over 94,000 Ci) of tritium and $1.38\times10^{+15}$ Bq (37,300 Ci) of tritium oxide. The effective oxide fraction for the aggregate source term is 40%.

Screening was performed against a criterion of a 1 in 100,000 added risk of fatal or non-fatal cancer, assuming a risk factor of 5.5% per sievert (Sv). This figure corresponds to a dose equivalent of 1.82×10^{-4} Sv. The residential population nearest each release point was selected as the exposed population for each screening assessment. The pathways considered for each residential location were contaminated air inhalation and contaminated soil and vegetable consumption. Consumption of locally raised meat or milk was not considered.

The first step of the NCRP Report No. 123 screening process is to perform a Level I screening evaluation, which is the simplest and most conservative type of evaluation. The Level I screen does not account for distance from the source to the receiver or for the associated atmospheric dispersion. If the Level I screening result exceeds the screening criterion, then a Level II approach, in which distance to the receiver and atmospheric dispersion are considered, is used next. In addition, in the Level II screen, the

screening criterion is reduced by an order of magnitude to account for uncertainties. If the Level II screening result exceeds the criterion, then a Level III screen is performed. In general, the Level III screen only differs from the Level II in terms of how dose pathways are considered. The approach used here for screening LANL's atmospheric tritium releases was hybridized, in that the appropriate pathways were accounted for from the outset, rather than first screening for all pathways and then removing the non-applicable pathways afterward.

A Level I screen was performed for the TA-3 release first, since it was the smallest contributor to the tritium oxide source term. If the Level I screening evaluation for the TA-3 release exceeded the screening criterion, there would be no need to continue with Level I screening for the other releases. As shown in Table 7-6, the Level I screening evaluation for the TA-3 source term exceeded the screening criterion by a substantial margin. Screening therefore proceeded to Level II/III.

Table 7-6. Level I screening for the maximum HTO release from TA-3

			Basis
Total Release =	3.84E+12	Bq HTO	Table 7-5
Seconds per year =	3.2E+07		NCRP 123 I-A-2
Annualized Release Rate =	1.2E+05	Bq/sec	(calculated)
Volumetric Flow Rate =	0.3	m^3/sec	NCRP 123 I-A-3
Exhaust vent concentration =	4.0E+05	Bq/m^3	(calculated)
Receiver concentration =	1.0E+05	Bq/m^3	calculated via NCRP 123 I-A-5
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	7.2E-02	Sv	(calculated)
Screening Criterion =	1.82E-04	Sv	1E-05 excess risk at 5.5% per Sv (ICRP 103)
Screening criterion exceeded? YES			

To proceed to Level II screening, the distance from each release point (TA) to the nearest residential area was estimated. Table 7-7 shows the location of the nearest residential area and the approximate distance in meters from each TA.

Table 7-7. Approximate distances from tritium release points to the nearest residents

Technical Area	Nearest Residents	Approximate Distance (m)
3	Western Area	1,740
15	Royal Crest Trailer Park	3,050
21	Group D Housing	540
33	White Rock	3,750
35	Royal Crest Trailer Park	1,740
41	Town Site Apartments	490

In the Level II screening process, the estimated distances from the release points to the nearest residential locations are used to determine a plume diffusion factor. These factors are determined from plots provided in NCRP Report No. 123. To simplify the process, the bounding value of the diffusion factor was selected for each source-receiver distance, thereby eliminating the need to account for effective release heights and the possibility of building wake effects. Such selection also added a further degree of conservatism.

Tables 7-8 through 7-13 below show the Level II[b] screening calculations for TAs 3, 15, 21, 33, 35, and 41, respectively. In each of the six Level II screening calculations, the screening criterion has been reduced by an order of magnitude (factor of ten) for an additional degree of conservatism per NCRP Report No. 123. Thus, the judgments as to whether the screening criterion has been exceeded are made against the adjusted, rather than the actual, screening criterion.

The screening evaluations show that only in the case of TA-35, for which the maximum release was treated as 100% HTO, was the adjusted screening criterion ever exceeded. In no case was the actual (unadjusted) screening criterion exceeded. If all of the screening results are summed, the result (9.17×10^{-5} Sv) is approximately half of the screening criterion of 1.82×10^{-4} Sv. Note that, in addition to the fact that the maximum release values are being treated as if they all occurred in the same time span, summing the individual screening values represents the physical impossibility of a hypothetical population of residents simultaneously living at a location nearest each of the individual release points. The screening dose for the aggregate releases would be much lower for any of the individual residential areas.

[b] In reality the Level II screening assessments may be thought of as Level III, since only the applicable pathways are being considered.

Table 7-8. Level II screening for the maximum tritium release from TA-3

Total Release =	3.84E+12	Bq HTO	Table 7-5
Seconds per year =	3.2E+07	sec	NCRP 123 I-A-2
Annualized Release Rate =	1.20E+05	Bq/sec	(calculated)
Wind Speed =	2	m/sec	NCRP 123 II-bi-7
Distance to receiver =	1740	m	estimated from LAHDRA project map
Dispersion factor =	2.5E-05	m^{-2}	NCRP 123 Fig. 1.4 (limiting value)
Receiver concentration =	3.75E-01	Bq/m^3	
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	2.70E-07	Sv	
Adjusted Screening Criterion =	1.82E-05	Sv	1E-05 excess risk at 5.5% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5
Screening criterion exceeded?	NO		

Table 7-9. Level II screening for the maximum tritium release from TA-15

Total Release =	4.07E+14	Bq HTO	Table 7-5
Seconds per year =	3.2E+07	sec	NCRP 123 I-A-2
Annualized Release Rate =	1.27E+07	Bq/sec	(calculated)
Wind Speed =	2	m/sec	NCRP 123 II-bi-7
Distance to receiver =	3050	m	estimated from LAHDRA project map
Dispersion factor =	9E-06	m^{-2}	NCRP 123 Fig. 1.4 (limiting value)
Receiver concentration =	1.43E+01	Bq/m^3	
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	1.03E-05	Sv	
Adjusted Screening Criterion =	1.82E-05	Sv	1E-05 excess risk at 5.5% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5
Screening criterion exceeded?	NO		

Table 7-10. Level II screening for the maximum tritium release from TA-21

Total Release =	2.97E+13	Bq HTO	Table 7-5
Seconds per year =	3.2E+07	sec	NCRP 123 I-A-2
Annualized Release Rate =	9.28E+05	Bq/sec	(calculated)
Wind Speed =	2	m/sec	NCRP 123 II-bi-7
Distance to receiver =	540	m	estimated from LAHDRA project map
Dispersion factor =	1.5E-04	m^{-2}	NCRP 123 Fig. 1.4 (limiting value)
Receiver concentration =	1.74E+01	Bq/m^3	
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	1.25E-05	Sv	
Adjusted Screening Criterion =	1.82E-05	Sv	1E-05 excess risk at 5.5% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5
Screening criterion exceeded?	NO		

Table 7-11. Level II screening for the maximum tritium release from TA-33

Total Release =	1.16E+13	Bq HTO	Table 7-5
Seconds per year =	3.2E+07	sec	NCRP 123 I-A-2
Annualized Release Rate =	3.63E+05	Bq/sec	(calculated)
Wind Speed =	2	m/sec	NCRP 123 II-bi-7
Distance to receiver =	3750	m	estimated from LAHDRA project map
Dispersion factor =	7E-06	m^{-2}	NCRP 123 Fig. 1.4 (limiting value)
Receiver concentration =	3.17E-01	Bq/m^3	
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	2.28E-07	Sv	
Adjusted Screening Criterion =	1.82E-05	Sv	1E-05 excess risk at 5.5% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5
Screening criterion exceeded?	NO		

Table 7-12. Level II screening for the maximum tritium release from TA-35

Total Release =	9.25E+14	Bq HTO	Table 7-5
Seconds per year =	3.2E+07	sec	NCRP 123 I-A-2
Annualized Release Rate =	2.89E+07	Bq/sec	(calculated)
Wind Speed =	2	m/sec	NCRP 123 II-bi-7
Distance to receiver =	1740	m	estimated from LAHDRA project map
Dispersion factor =	2.5E-05	m^{-2}	NCRP 123 Fig. 1.4 (limiting value)
Receiver concentration =	9.03E+01	Bq/m^3	
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	6.50E-05	Sv	
Adjusted Screening Criterion =	1.82E-05	Sv	1E-05 excess risk at 5.5% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5
Screening criterion exceeded?	YES		

Table 7-13. Level II screening for the maximum tritium release from TA-41

Total Release =	5.84E+12	Bq HTO	Table 7-5
Seconds per year =	3.2E+07	sec	NCRP 123 I-A-2
Annualized Release Rate =	1.83E+05	Bq/sec	(calculated)
Wind Speed =	2	m/sec	NCRP 123 II-bi-7
Distance to receiver =	490	m	estimated from LAHDRA project map
Dispersion factor =	2E-04	m^{-2}	NCRP 123 Fig. 1.5 (limiting value)
Receiver concentration =	4.56E+00	Bq/m^3	
Screening Factor =	7.20E-07	Sv per Bq/m^3	NCRP 123 Table B.1 (inhalation + vegetables + soil)
Screening Value =	3.29E-06	Sv	
Adjusted Screening Criterion =	1.82E-05	Sv	1E-05 excess risk at 5.5% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5
Screening criterion exceeded?	NO		

The NCRP Report No. 123 screening evaluation suggests that airborne tritium releases from LANL were unlikely to have been a source of adverse health risks to local residents around Los Alamos. The possibility cannot be ruled out entirely, however, in light of the screening result for TA-35. Further, there are caveats to consider, including the possibility that larger releases could have occurred prior to 1967 (when atmospheric tritium releases were first estimated by LANL), or that some of the releases consisted of a greater fraction as tritium oxide (HTO) than has been considered here. But, given the degree of conservatism used in the screening method, the impacts of such effects would have to be substantial before atmospheric tritium releases would have posed a significant health risk.

As a check on the intended conservatism in the screening approach used for atmospheric tritium releases, local environmental monitoring data for tritium oxide (HTO) were compiled for the period from July, 1970 through December, 1979. This period was expected to encompass the largest airborne tritium releases from LANL for the era when environmental monitoring data are available. Table 7-14 shows the maximum annual average concentrations for the on-site and off-site environmental tritium monitoring stations on and around the LANL site for July, 1970 to December, 1979. The on-site data were included in this evaluation to both be conservative and to allow for the fact that the public historically has had access to many "on-site" locations at LANL.

Table 7-14. Maximum tritium oxide concentrations from the LANL environmental air monitoring stations 1970–1979

Year	Maximum On-Site Average		Maximum Off-Site Average		LAHDRA Reference (Repos. No)
	Concentration ($\mu Ci\ mL^{-1}$)	Location	Concentration ($\mu Ci\ mL^{-1}$)	Location	
1970*	1.80×10^{-11}	unknown	3.50×10^{-12}	"Community"	2178
1971	2.40×10^{-10}	Array 156-9.4	1.20×10^{-10}	Array 42-3.1	2155
1972	1.80×10^{-10}	Array 156-9.4	4.40×10^{-11}	Array 164-8.5	887
1973	1.51×10^{-10}	TA-21	2.70×10^{-11}	Fuller Lodge	2161
1974	1.41×10^{-10}	TA-33	3.60×10^{-11}	Fuller Lodge	2157
1975	1.74×10^{-10}	TA-52	9.30×10^{-11}	Fuller Lodge	2158
1976	3.30×10^{-10}	TA-54	5.10×10^{-11}	Los Alamos airport	2159
1977	1.87×10^{-10}	TA-54	5.10×10^{-11}	Los Alamos airport	2069
1978	5.70×10^{-11}	TA-54	2.60×10^{-11}	Los Alamos airport	953
1979	4.00×10^{-11}	TA-33	6.70×10^{-12}	Royal Crest Trailer Park	2190

*July – December, 1970

The elevated HTO concentrations at TA-54 are the result of evaporative losses from soil containing buried, tritium-contaminated wastes. Tritium oxidizes slowly in the environment, at a rate of less than 1% per day (Mishima and Steele, 2002). The fact that the TA-54 sampling station is the location of the maximum measured on-site HTO concentrations for some years shows the importance of TA-54 as a source of airborne releases of tritium oxide relative to other sources. The tritium oxide concentration for the TA-54 environmental monitoring station for 1976 was the largest of all of the on-site annual averages for July, 1970 through December, 1979. The largest off-site annual average for this period was at the location designated Array 42-3.1 for 1971. It is difficult to discern the precise location of this monitoring station in the reference, but it appears that it might be at or near the Fuller Lodge location.

As shown in Table 7-14, the maximum annual average airborne tritium oxide concentrations reported by the LANL environmental air monitoring network for July, 1970 through December, 1979 were 3.3×10^{-10}

$\mu Ci\ mL^{-1}$ (12.2 Bq m^{-3}) and 1.2×10^{-10} $\mu Ci\ mL^{-1}$ (4.4 Bq m^{-3}) for on-site and off-site locations, respectively. To gauge the implications of these concentrations in terms of dose to human receivers, screening factors for tritium oxide from NCRP Report No.123 can be applied. For the on-site locations, for example, the appropriate factor to use is the one for inhalation alone. The combined factors for contaminated vegetable and soil inhalation and consumption are appropriate for the off-site locations. These screening factors are 1.4×10^{-7} Sv per Bq m^{-3} for inhalation and 7.2×10^{-7} Sv per Bq m^{-3} for the combination of inhalation and consumption of contaminated vegetables and soil.

Multiplying the inhalation screening factor by the maximum on-site concentration value (in consistent units) results in a screening dose equivalent value of 1.7×10^{-6} Sv, or 0.17 mrem. Note that this calculation requires the extremely conservative assumption of 100% occupancy at the on-site location. The same calculation for maximum average off-site concentration, using the combined factor for inhalation and vegetables, results in a screening dose equivalent of 3.2×10^{-6} Sv, or 0.3 mrem. If the vegetation pathway is included, however, the resulting screening dose is higher than the on-site location, despite the lower average air concentration. Nonetheless, both of these values are well below the screening criterion of 1.82×10^{-4} Sv (18.2 mrem).

As with the screening assessment performed using atmospheric release data for tritium, measured values of tritium oxide concentrations in the local environment around Los Alamos also suggest that airborne releases of tritium from LANL are unlikely to have resulted in any adverse health risks to the local residents. However, as with the effluent data, the environmental monitoring data have been used as reported without any adjustments or verification, and they do not consider the period prior to 1970.

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Chapter 8: Hot Cell Facilities and Operations at LANL

Beginning with early operations, LANL processed highly radioactive material, such as fission products, to meet both its production and research needs and those of the federal government. Much of LANL's work on radioactive materials was carried out in specialized, shielded enclosures called "hot cells" that provided protection for workers by reducing their radiation exposures. Remote manipulators, also called mechanical hands, were used to handle isolated radioactive materials inside the hot cells. The hot cells also provided some level of control in helping to reduce releases of radioactive material to the environment.

In 1944, LANL began receiving its first shipments of multiple curies of ^{140}Ba for use in extracting ^{140}La, a radionuclide used as a tracer for hydrodynamic explosive tests conducted during the Radioactive Lanthanum ("RaLa") program. Because of the high gamma energy and radiation fields associated with these materials, LANL designed and built its first hot cell facility in order to safely extract the ^{140}La for further processing. Over the course of many years, LANL built several additional hot cell facilities to meet the growing needs of the federal government and other customers, and, by the early 1980s, had approximately 36 hot cells in operation.

In addition to ^{140}Ba/^{140}La operations, hot cells were used for (Wilson et al., 1979):

- handling and manufacturing of nuclear reactor fuels and fuel assemblies;
- chemical separation and analysis of irradiated reactor fuels;
- radionuclide analyses, such as with fission products, to support nuclear weapon tests;
- accelerator-based production of radionuclides for medical and research applications;
- fabrication and testing of fuels associated with the Rover nuclear propulsion and the Ultra High-Temperature Reactor Experiment (UHTREX) projects;
- storage and processing of materials with high tritium concentrations; and
- chemical separation, isotopic analysis, treatment and volume reduction, and high-level radioactive waste storage in support of a variety of LANL and other governmental programs.

LANL's hot cell facilities were used for handling large quantities of fission products, and, to a lesser extent, plutonium, uranium, and other heavy elements. Because of the higher radioactivity handled in these facilities, the project team collected information on hot cell operations to support potential prioritization of associated future releases. This chapter provides an overview of LANL's hot cell operations, and highlights those that may warrant further investigation. In preliminary prioritization

analyses, fission products were found to be less important than several other classes of radionuclides. The analyses performed to date, however, have been largely dependent on release estimates put forward by LANL, and waste streams associated with hot cell operations appear to not always have been among the top priorities within programs for monitoring and estimating releases to the environment. Several comments have been made during past LAHDRA public meetings that indicate that some members of the public believe that releases from hot cell operations have not been adequately disclosed, characterized, or quantified. Some believe that releases of radioiodine and other fission products could have been significantly larger than has been disclosed, and that an independent evaluation of associated historical activities is warranted. A summary of LANL hot cell operations is presented in Table 8-1.

Over 8,000 documents or sets of documents that are included in the LAHDRA project information database were searched by team members for information pertaining to hot cell and associated operations. A summary of related information that has been extracted is presented below.

Table 8-1. Hot Cell Operations at LANL (Wilson et al, 1979)

TA	Purpose	Dates	Radionuclides/Chemicals
1	Radiochemical and radiotracer separation (including RaLa operations) and neutron source preparation. Most of these operations took place in H Building.	1944 -1957	^{140}Ba, ^{140}La, ^{90}Sr,. ^{210}Po, ^{226}Ra, Be
3	CMR Building Wing 9 Hot Cell Facility. Used to evaluate irradiated plutonium and uranium fuel and fission products testing and separation and post detonation debris radiochemical analyses. Operations occurred largely in Wing 9 of CMR Building. The facility contained 16 general purpose cells 2m by 2m by 3.6m high.	1961-present	^{239,238}Pu, ^{234,235,238}U, mixed fission products, mixed activation products, TRU
10	Early RaLa sources were prepared in Bayo Canyon and later in facilities at Ten Site (TA-35). RaLa explosive experiments were completed in Bayo canyon. Remote handling, telescopes, and mirrors were used to aid in the separation and preparation of the ^{140}La. A few hundred thousands curies were handled during almost 20 y of RaLa explosive testing. Some batches of La reached upwards to 5,000 Ci. Single sources for test shots ranged from 40 to over 3,000 Ci.	1944-1951	^{140}Ba, ^{140}La, ^{90}Sr,. ^{210}Po, ^{226}Ra, Be
18	Rover Program - Hot Cell facility	1955-1973	Pu, U, and fission products
21	Examination of irradiated Pu and enriched uranium from Omega reactor (such as ^{235}U impregnated with graphite and ^{239}Pu in stainless steel casing and a tantalum sheath) and separation of irradiated fuel and fission products. The facility had four primary hot cells that were designed primarily to evaluate plutonium reprocessing schemes. Fuel reprocessing experiments and tests were discontinued in 1967. In the 1970s, the hot cells were used to evaluate irradiated fuel elements associated with the LMFBR program. Operations occurred largely in Bldg 4, Room 401. Rooms 403 through 407 contained gloveboxes used for metal preparation of ^{238,239}Pu. High exposure rates during material transfers to hot cells. After tests were completed, irradiated fuel was transferred from hot cells to the "hot dump." On 26 May 1961, special fiberglass filter papers were placed in cell, corridor, and stack exhaust lines in Room 401 to sample air for fission products.	1958 - 1978	^{3}H, ^{239,238}Pu, ^{234,235,238}U, mixed fission products
33	Tritium handling facilities that contained hot cells for source handling and processing.		^{3}H
35	Radiochemical and radiotracer separation (RaLa operations), neutron source preparation, and fuel separation. Starting in 1956, the Chemical Processing Plant at Idaho Falls provided purified ^{140}Ba. Almost 2 million Ci were processed at Ten Site by 1963 when the RaLa program was terminated. Irradiated fuels from the LAPRE I and II and LAMPRE reactors were also evaluated in hot cells located at Ten Site. First hot cell design after WWII for handling high-level radioactive materials.	1951-1963	^{140}Ba, ^{140}La, ^{90}Sr,. ^{210}Po, ^{226}Ra, mixed fission products, Be
48	Radiochemistry Hot Cell Facility. Used to perform actinide chemistry and isotope production/separation. Facility also used to analyze samples collected from nuclear weapon test shots. In 1963, another hot cell facility was built in an adjacent structure to evaluate and dissolve samples of graphite fuel from the Rover Program. The Rover Program ended in 1973.	1959-present	Pu, U, TRU, mixed fission products, and mixed activation products
50	Contaminated Hot Cell facility. This facility was designed to handle high-level beta and gamma emitting wastes from several groups at LANL. The hot cells were part of the Contaminated Waste Treatment Plant. The cell was primarily used to neutralize liquid waste and package it for permanent storage.	1963-present	Pu, U, TRU, mixed fission products, andmixed activation products
52	UHTREX high-level remote handling area consisted of one hot cell for fuel element changing and examination.	1961-1968	Pu and U
53	LAMPF and LANSCE facilities contain two hot cells used for radiochemical experiments of irradiated targets, isotope production, and mixed activation products.	1976-present	^{3}H, mixed activation products

The RaLa Program

Chemical extractions of lanthanum during the initial years of the program for testing the implosion process (1944-1950) were performed using 1.5- to 2- m high shielded shipping casks, and were carried out in a wooden building located in Bayo Canyon, TA-10 (Wilson et al., 1979). Operators located approximately 27 m from the casks using electric cranks, cabling, and remote tongs, along with telescopes and mirrors for viewing, lowered reagents into casks to complete the chemical separation of barium and lanthanum. One hundred and fifty sources of ^{140}La, ranging in source strength from 40 to over 3,000 Ci, were prepared and used in explosives tests from September, 1944 to July, 1950. The crude remote handling facility used at TA-10 was modest by today's standards for hot cell design and performance, but it served its purpose until it was phased out of operations in the early 1950s.

In 1947, LANL began constructing a new hot cell facility at Ten Site (TA-35) to process barium and lanthanum. Completed in 1951 at a cost of nearly $3 million, the facility consisted of two 3-m by 6-m by 2.5-m high hot cells. A crane and trolley system was used to move radioactive materials in and out of the cells. The trolley housed a rotatable spindle with pins on one end to mate with bayonet slots of various tools, vessels, and equipment components inside the hot cells for handling and processing materials. An operator's view inside a hot cell was accomplished with shielded glass windows (such as leaded glass) and a series of mirrors and retractable periscopes. A large auxiliary building was used to handle and purify air and house liquid filtration and treatment equipment. Believed to have been the first modern hot cell design to handle high-level radioactive materials, the TA-35 facility contained innovative features, such as exterior, contamination–free lighting, cell wash-down sprays, collimated ports for experiments, and hydraulic rams for opening and handling shipping casks. LANL later added concrete caves with a zinc bromide window above the hot cells to provide flexibility for packaging lanthanum sources. In 1963, these operations terminated after processing about two million curies from the Chemical Processing Plant at the Idaho Falls (Wilson et al., 1979).

Hot Cells Associated with LANL Reactors

A series of research and production reactors were operated at LANL as far back as 1943. These reactors were largely used in fuel and neutron experiments and for fission and activation product research and production (Wilson et al., 1979). The first of these reactors were the water boiler series reactors (LOPO, HYPO, and SUPO) as described in Chapter 5. The Clementine reactor, located at Omega Site (TA-2) at the bottom of Los Alamos Canyon, was commissioned in November, 1946, and was the first reactor to use ^{239}Pu for fuel. Hot cells were used to test the fuel and reactor components following neutron

irradiation experiments. Corrosion of steel cladding began to release considerable alpha contamination into the mercury coolant, which led to the reactor's shutdown and decommissioning in 1952. According to LANL employees, no detectable radioactivity was released to the environment during these fuel rod failures (Wilson et al., 1979).

The OWR was built at the same location as Clementine, and was operated from 1956 to 1994 to support a variety of research programs. Irradiated fuel from Omega West was transferred to hot cells for chemical processing and testing. In some cases, isotopes were extracted to support or research programs.

LANL used a series of compact reactors assembled and tested at Ten Site in the 1950s and 1960s to test new technologies used in reactor and fuel assembly designs. This project was called the Los Alamos Power Reactor Experiment (LAPRE), and it used plutonium dissolved in phosphoric acid. LAPRE I was a forced-convection, high pressure, water-cooled reactor that was later drained and decommissioned. LAPRE II used natural convection, operated for short time, and then was shut down. Irradiated fuel and reactor components and equipment were tested inside the TA-35 hot cells. Typical processes involved chemical separation, radionuclide analytical measurements, and waste disposal preparation. A third reactor, known as the Los Alamos Molten Plutonium Reactor Experiment (LAMPRE), operated within the Ten Site hot cell adjacent to the one used to extract ^{140}La in the RaLa program. The fuels from these reactors were eventually transferred for storage to the CMR Wing 9 hot cell facility at TA-3 for further processing and waste disposal (Wilson et al., 1979).

General Purpose Hot Cells

Since 1951, LANL has operated 36 general purpose hot cells in four separate on-site facilities. These are described as general purpose cells because their designs permitted considerable flexibility for radioactive material storage, processing, and handling. This section presents a description of each of these facilities. Hot cell operations are active, or have been active, at the following LANL facilities:

- TA-3, CMR Building, Wing 9 Operations
- TA-21, DP West Site, Building 4, Room 401,
- TA-48, Radiochemistry LaboratoryTA-50, Contaminated Waste Treatment Facility
- TA-52, UHTREX Facility and
- TA-53, LAMPF/LANSCE Facility

TA-3; CMR Building Wing 9 Hot Cells

The CMR Wing 9 hot cell facility began operating in December, 1961. The facility was used to support the civilian power reactor program from 1961 to 1967, the Rover Nuclear Propulsion Project from 1961 to 1973, and the Liquid Metal Fast Breeder Reactor (LMFBR) from 1967 to the early 1980s. The facility has also provided assistance to numerous LANL programs by performing various experiments involving high levels of gamma radiation associated with irradiated fuel and fission product samples. The facility still supports a variety of LANL programs, including transuranic (TRU) waste treatment and packaging for disposal at the DOE WIPP site in Carlsbad, New Mexico (LANL, 1999).

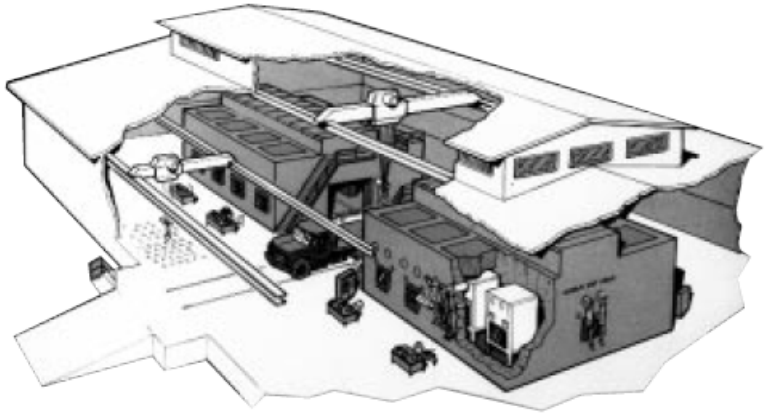


Fig. 8-1. Wing 9 hot cell facility at TA-3's CMR Building (LANL, 1999)

The Wing 9 hot cell facility consists of sixteen 2-m by 2-m by 3.6-m high hot cells arranged in two groups of eight cells separated by shielded corridors. Fig. 8-1 represents a cutaway drawing of the Wing 9 hot cell facility. The ferro-phosphorus walls and leaded-glass windows shield up to 30,000 Ci of mixed fission products or 50,000 Ci of 1 MeV gamma radioactivity (Valentine et al., 1969, Wilson et al., 1979). A storage area consists of 364 shielded holes that are cooled and maintained at negative pressure. Areas within the facility are designed for decontamination activities, mock-up runs, machine shop, manipulator repair, cold laboratory, dark room, and staff offices. Fig. 8-2 is a photograph showing the exterior work stations and the shielded glass viewing windows, manipulator arms, and control panels for a group of four Wing 9 hot cells located in the CMR Building.

Airborne effluents from the CMR Wing 9 hot cells are filtered and monitored for particulates and radioiodine with fiber and charcoal filters, respectively. Air from three monitored compartments is discharged at a rate of 176,840 ft^3 min^{-1} through a 56 ft tall stack. Air samples are collected on a 24-h basis and analyzed for ^{235}U, ^{238}U, ^{239}Pu, ^{241}Am, fission products, and ^{131}I. Sampling results and details of the sampling program were reported in LANL reports and were reviewed by the LAHDRA team. Early

effluent monitoring results are published in monthly Health Division reports and special reports that present monitoring results for non-routine releases, as well as discussion of general issues relating to stack monitoring and airborne emissions and their environmental impact. Monitoring results are also published in LANL's Annual Environmental Surveillance reports for the years 1970 to the present.

Fig. 8-2. CMR Building Wing 9 hot cells

Stack sampling and filtering of effluents for the Wing 9 hot cells began at the start of operations, and underwent of number of changes and improvements over the years. In a 1970 memorandum, LANL reported that the CMR stack sampling was not isokinetic, results were therefore not representative of quantities actually discharged, and improvements were needed in order to generate reliable release estimates (Graham, 1952). Upgrades and new procedures were implemented to improve the exhaust filtration and monitoring program, as highlighted in numerous Health Division reports and memorandums (Graham, 1952). Efforts to reduce emissions were also emphasized during this period because of the forthcoming AEC release limit reductions for radioactive isotopes. Other reports also depicted LANL's efforts to improve the monitoring and control of airborne releases from other CMR wings and exhaust stacks (LASL, 1975).

Solid radioactive waste from these and other hot cell operations were disposed of at the former TA-21 and TA-54 burials grounds. Waste was often treated or consolidated and packaged into a variety of containers (such as 55-gallon metals drums) and transported to the burial grounds for shallow-land burial. Land burial at LANL began during the 1940s and continued up through recent years.

Small volumes of liquid waste from hot cell operations containing plutonium, americium, uranium, and fission products, along with reacted sodium and sodium potassium solutions, were placed in 3.8 L or smaller containers and then packed in 7.8 L cans with dry vermiculite for shaft burial at the burial grounds. Other waste containing higher levels of radioactivity were transported to TA-50 for treatment (LASL, 1975).

T-21; DP West Site Room 401 Hot Cells

Construction of four hot cells began in 1958 in Building 4 at TA-21. These cells were designed to handle kilogram quantities of irradiated plutonium possessing kilocuries of gamma activity, and to support evaluation of plutonium fuel reprocessing schemes up through 1967. The facility then remained idle for the next three years, until the cells were used to perform in-depth, post-irradiation examinations of reactor fuel elements. The 2-m by 2-m by 6.5-m high cells were interconnected by a 3-m by 10-m, shielded corridor with rolling steel doors and 22, 1.5 m deep storage wells located on the floor. The cells were equipped with manipulators for remote processing, and radioactive material was moved in and out via a transfer can system. This facility was partially decommissioned in the 1980s, and has been under a maintenance and preservation program since. The future plans for many of the buildings at TA-21 are currently under review by LANL.

The Room 401 hot cells were designed with a negative pressure water circulating system. If the system were breached, air would leak into the system instead of water leaking into the cells. This design minimized the chances of a nuclear criticality accident, and reduced the potential for a large of amount of contaminated water that would have otherwise flooded the cells. This design did, however, create airborne emission concerns.

As reported in two 1961 Health Division memos regarding the DP West Room 401 Hot Cells, LANL recognized that process air concentrations and releases of ^{131}I had become a concern and needed to be addressed by using improved source control and exhaust vent and stack filtration (Dummer, 1961). Fig. 8-3 provides an example report of air concentrations above the maximum permissible concentrations (MPCs) highlighting those concerns. The elevated air concentrations were due to the dissolution and analysis processing of an 82-g plutonium foil that had been irradiated in the Omega West Reactor. The reports suggest that this occurrence was not unique, and that greater attention was needed in order to reduce such airborne emissions in the future.

TABLE I
401 DRYBOX EXHAUST I^{131}

Date Collected	$d/m\text{-}M^3$ on Filter Corrected for Decay	$d/m\text{-}M^3$ Corrected for Filter Paper Efficiency*	% MPC**
6-2-61	3.8×10^5	3.8×10^8	130
6-5-61	3.8×10^5	3.8×10^8	130
6-6-61	4.2×10^5	4.2×10^8	140
6-7-61	9.0×10^5	9.0×10^8	300
6-8-61	6.6×10^5	6.6×10^8	230
6-9-61	5.2×10^5	5.2×10^8	180
6-12-61	6.6×10^5	6.6×10^8	230
6-13-61	3.4×10^5	3.4×10^8	120
6-14-61	2.2×10^5	2.2×10^8	76

Fig. 8-3. DP West hot cell ^{131}I air sample results (from Dummer, 1961)

LANL also stated in memos that, before another sample was run, some effort to prevent iodine dispersal should be made; that is, charcoal filters should be installed at the drybox exhaust ports (Dummer, 1961).

TA-48 Radiochemistry Hot Cell Facility

The TA-48 Radiochemistry Hot Cell Facility became operational in 1959, and was designed for irradiated fuel and fission product evaluations and experiments. The facility was also used for other programs, such as actinide chemistry experiments, isotope separation and production for medical and research uses, in-depth fuel analyses, and fission product and fuel testing of samples collected following nuclear weapon detonation tests (Wilson et al., 1979). The first cell utilized three work stations, and was design to store and handle hundreds of curies of radioactivity. TA-48 hot cells are still in use today for processing, testing, and storing radioactive materials (Vergamini, 1991).

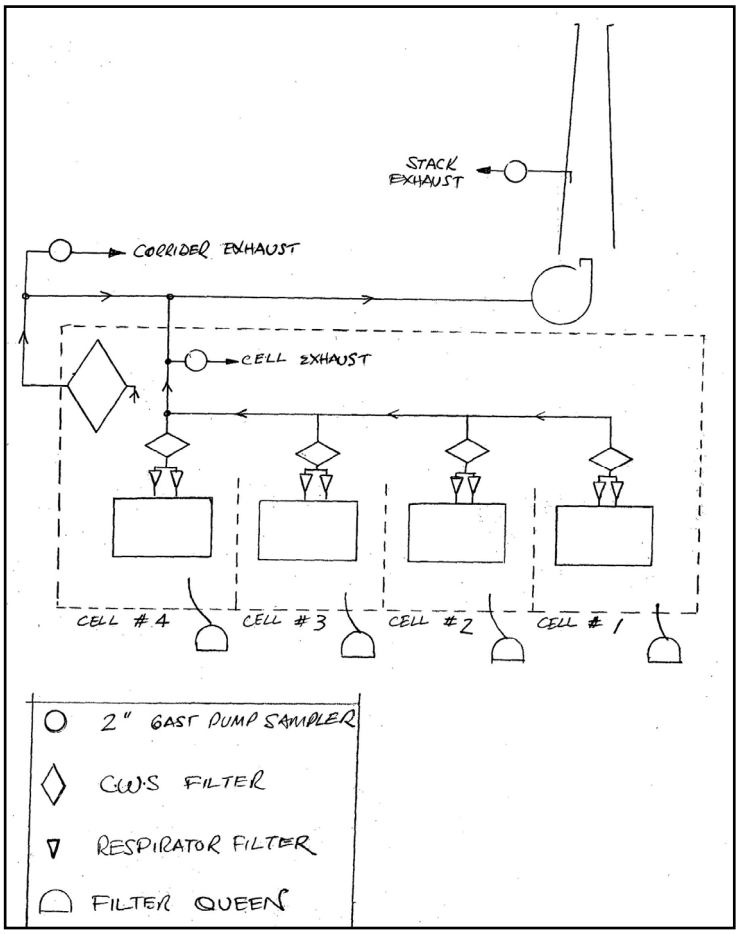
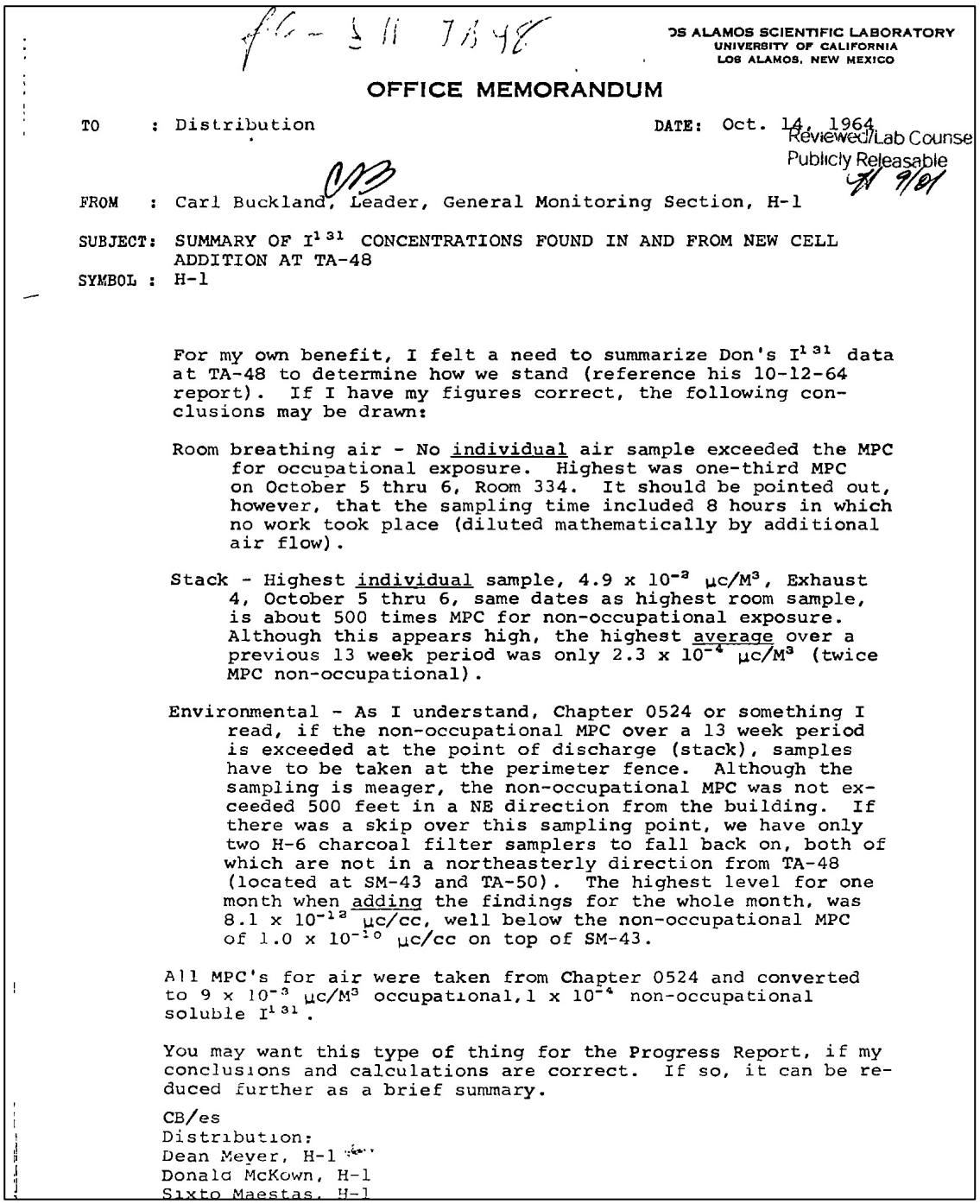


Fig. 8-4. DP West hot cell layout showing monitoring and filters (Dummer, 1961)

In 1963, twelve more cells were built in an adjacent building at TA-48 for dissolving and evaluating graphite fuel used in the Rover program. The cells are 1.5-m by 1.7-m by 2.7-m high, and arranged in two rows of six separated by a shielded corridor. The Rover project ended in 1973, and some of the cells were later modified to handle uranium, plutonium, transuranics, and fission products. Releases of ^{131}I and other fission products gained the attention of LANL staff. While it is unclear how rapidly LANL responded to the issue, it is clear that Health Division staff published their concerns about the issue during early operations.

Figure 8-5 presents an example of a LANL document that highlights radioiodine releases and concerns about off-site emissions from the TA-48 hot cells. Much of LANL's concerns focused on residents living in a nearby trailer court (Royal Crest Trailer Park) located approximately 1000 m from the TA-48 exhaust stack. Hot cells at TA-48 were used to experiment with a variety of less commonly used radionuclides such ^{227}Ac, ^{76}Br, ^{77}Br, ^{82}Br, and ^{237}U.



LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

OFFICE MEMORANDUM

TO : Distribution

DATE: Oct. 14, 1964

Reviewed/Lab Counse
Publicly Releasable
9/01

FROM : Carl Buckland, Leader, General Monitoring Section, H-1

SUBJECT: SUMMARY OF I^{131} CONCENTRATIONS FOUND IN AND FROM NEW CELL ADDITION AT TA-48

SYMBOL : H-1

For my own benefit, I felt a need to summarize Don's I^{131} data at TA-48 to determine how we stand (reference his 10-12-64 report). If I have my figures correct, the following conclusions may be drawn:

Room breathing air - No individual air sample exceeded the MPC for occupational exposure. Highest was one-third MPC on October 5 thru 6, Room 334. It should be pointed out, however, that the sampling time included 8 hours in which no work took place (diluted mathematically by additional air flow).

Stack - Highest individual sample, 4.9×10^{-2} $\mu c/M^3$, Exhaust 4, October 5 thru 6, same dates as highest room sample, is about 500 times MPC for non-occupational exposure. Although this appears high, the highest average over a previous 13 week period was only 2.3×10^{-4} $\mu c/M^3$ (twice MPC non-occupational).

Environmental - As I understand, Chapter 0524 or something I read, if the non-occupational MPC over a 13 week period is exceeded at the point of discharge (stack), samples have to be taken at the perimeter fence. Although the sampling is meager, the non-occupational MPC was not exceeded 500 feet in a NE direction from the building. If there was a skip over this sampling point, we have only two H-6 charcoal filter samplers to fall back on, both of which are not in a northeasterly direction from TA-48 (located at SM-43 and TA-50). The highest level for one month when adding the findings for the whole month, was 8.1×10^{-12} $\mu c/cc$, well below the non-occupational MPC of 1.0×10^{-10} $\mu c/cc$ on top of SM-43.

All MPC's for air were taken from Chapter 0524 and converted to 9×10^{-3} $\mu c/M^3$ occupational, 1×10^{-4} non-occupational soluble I^{131}.

You may want this type of thing for the Progress Report, if my conclusions and calculations are correct. If so, it can be reduced further as a brief summary.

CB/es
Distribution:
Dean Meyer, H-1
Donald McKown, H-1
Sixto Maestas, H-1

Fig. 8-5. 1964 H-Division memo addressing airborne iodine releases at TA-48 (Buckland, 1964)

LANL took steps to reduce these iodine releases by adding additional charcoal filters to exhaust air systems. It also improved its stack sampling and monitoring systems and practices over time so that results more accurately quantified releases to the environment (Neely, 1967).

Process air from TA-48 hot cells and surrounding areas was consolidated and exhausted through two main exhaust plenums (designated as FE-38 and FE-48), and then vented to the outdoor atmosphere

through an elevated stack (Maestas, 1971). The Maestas references cited here are sample reports selected from a series of weekly Health Division reports located in the LAHDRA database.

TA-50 Contaminated Waste Treatment Plant Hot Cell Facility

As part of the Chemical Waste Treatment Plant at TA-50, a hot cell facility became operational in 1963 to handle high levels of beta-gamma emitting radioactive material. The hot cell facility was primarily used to neutralize liquid waste and package the treated and consolidated waste for long-term storage and disposal. The facility consisted of a cask unloading dock, transfer and storage area, and one 2-m by 3-m by 4-m high hot cell.

TA-52 UHTREX Hot Cell

This hot cell was built in 1965 to provide a properly-shielded place to exchange fuel assemblies and test irradiated fuel. The facility was shut down in 1968 along with the UHTREX project.

Fast Reactor Core Test Facility

Construction of this facility began in 1963 and was completed in 1966. The project and associated use of the hot cell facility for handling plutonium fuel was terminated before any of the systems or structures were tested or used.

TA-53 LAMPF/LANSCE

The accelerator complex at TA-53 contains two hot cells with four work stations. These hot cells have been in operation since 1976. The cells are used for radiochemical experiments and medical and research isotope production and separation. Isotope separation was also performed inside the hot cells at Wing 9, CMR Building at TA-3.

Hot Cell Decontamination and Waste Disposal

The largest amount of radioactive waste generated by hot cell operations came from the hot cells located at TA-3 (Wing 9), TA-21 (Room 401), TA-35 (Ten Site Laboratory), TA-48 (Radiochemistry Laboratory), and TA-50 (Waste Treatment Plant). Methods used to decontaminate, treat, and dispose liquid and solid waste from LANL's hot cell operations varied according to the levels of radioactivity and the types of radioactive materials processed in a given project. Much of the removal, treatment, consolidation, and disposal of highly radioactive residues and wastes generated inside hot cells involved using remotely-operated jet spray washing, and dry and wet vacuum systems (Dummer, 1965, LANL,

1974). Highly radioactive liquid waste was treated at the Contaminated Waste Hot Cell facility located at TA-50

Removing and collecting contaminated radioactive waste and subsequently treating it for on-site disposal at a typical LANL hot cell involved the following procedures:

- Removable contamination was spray-washed from containment structures (such as bench tops and laboratory exhaust hoods) and from equipment and tools, and then vacuumed into holding containers.

- Spray washing to remove loose contamination was repeated until levels allowed personnel to enter the hot cells for short periods to apply more aggressive measures, such as acid washing and scrubbing to lower contamination to acceptable levels.

- Soaking highly contaminated, smaller equipment and tools in containers filled with a mixture of CH_2Cl_2 (dichloromethane or methylene chloride), detergents, and hot water. This process proved to be an effective means of removing radioactive residues. The foaming action of the mixture carried off much contamination in precipitates that were collected, treated, and/or disposed.

- Dry solid residues and debris were vacuumed with in-cell vacuum systems and collected in containers. Recovered material considered to be valuable was sent for further separation, analysis, and recycling.

- At Ten Site (TA-35 hot cells), highly radioactive residues were evaporated to dryness, placed in pressure-sealed, aluminum containers, and loaded into uranium casks. The casks were then loaded on trucks and transported to the TA-21 disposal area for burial in 2-ft diameter by 15 ft deep holes in the ground. When burial activities at TA-21 ceased, LANL began using the burial grounds at TA-54 to meet their disposal requirements for these wastes.

- Highly radioactive solid waste was loaded into aluminum or stainless steel containers and placed in uranium casks for burial at the TA-21 disposal area. In later years, these wastes were transported to the burial grounds at TA-54. During the early period of the 1950s and 1960s, liquid wastes were mixed with concrete and vermiculite and buried as solid waste.

- At the Wing 9 facility (TA-3 hot cells), cells dedicated to uranium and plutonium fuel work used open containers inside the hot cells. Dry debris and dust generated from cutting, crushing, and drilling the fuel was collected with an in-cell vacuum system equipped with a cyclone separator, a

CWS filter, and a charcoal adsorption bed. Liquid and solid wastes were collected, treated, and consolidated for land burial using similar methods.

- By the 1970s, liquid wastes with recoverable amounts of radioactive materials were sent to hot cells at TA-50 for separation (such as cation exchange processing), analyzed, and returned to LNL generators for reuse and/or further analyses. Waste contents with 10^{-3} μCi mL^{-1} alpha and/or 10^{-2} μCi mL^{-1} beta concentrations were disposed of as low-level radioactive waste. If concentrations were above these values, the waste was placed in portable stainless steel tanks and delivered to the TA-50 Waste Treatment facility for recovery and consolidation (LANL, 1974).

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Chapter 9: Operations with Other Radionuclides

Uranium

As discussed in numerous places in this report, uranium, at various levels of ^{235}U enrichment, has been used in a wide variety of applications at LANL.

Uses of Uranium in Weapons

To develop and build gun-assembled weapons, LANL personnel initially experimented with using enriched uranium (^{235}U) and plutonium as the fissionable material. The gun-assembled uranium weapon was carried into production, and some implosion-assembled weapons that came along later included uranium as a fissile material. In addition, heavy metals, such as uranium, were used as "tampers" that confined the explosion, reflected some neutrons that would otherwise escape, and thereby decreased the "critical mass" of fissile material required to achieve an atomic explosion (Serber et al., 1992).

Uses of Uranium in Reactors

Uranium in liquid and solid forms was also used as fuel in various nuclear reactors (more details can be found in Chapter 5). The first Water Boiler reactor was assembled in late 1943 at Omega Site (TA-2), using the nation's total supply enriched uranium as fuel in the form of 14%-enriched uranyl sulfate. The Plutonium Fast Reactor (Clementine) used plutonium fuel that was surrounded by a 6-inch thick natural uranium reflector, and reactivity control was achieved via inserting uranium fuel rods. The LAPRE I reactor experiment studied the use of phosphoric acid solutions of high-enriched uranium in a high-temperature reactor fuel, as did LAPRE II. The Ultra High Temperature Reactor Experiment (UHTREX) used 93%-enriched uranium fuel in the form of small spheres of UO_2 coated with pyrolytic carbon and bound in a graphite matrix. That fuel was fabricated at the CMR Building in TA-3. A 1969 waste management plan says that the DP East facility processed new Rover fuel elements containing enriched uranium.

Facilities that Handled Uranium

From 1948 to 1960, DP West Site's Building 4 housed laboratories for production of enriched uranium hydride. In 1960, the hydride equipment was removed so that a hot cell could be added for the examination of irradiated plutonium and enriched uranium fuel elements.

Facilities at the Original Technical Area (TA-1) that housed uranium operations included:

- C-Building– housed a normal machine shop with a uranium machine shop in southeast section. Became operational in October, 1943.

- D-Building– a facility designed to carry out chemistry and metallurgical experiments on plutonium and uranium. Other activities included tamper and polonium initiator design and various refractory material development.

- G-Building– housed the uranium and graphite "Sigma Pile," plus leak-testing of radium sources. Removed in June, 1959.

- HT-Building– heat treatment and machining of normal and enriched uranium.

- HT Barrel House– contained storage areas for ^{239}Pu and ^{235}U.

- M-Building– housed processing, metallurgy, and recovery of enriched uranium.

- Sigma Bldg– housed casting, machining, powder metallurgy of normal and enriched uranium, and thorium (eastern part was normal; western part was enriched).

- TU-Building– housed machining of normal uranium ("tuballoy").

- TU-1 Building– housed recovery of enriched uranium.

- V-Building– contained the original machine shop; uranium and beryllium were machined there.

The Sigma Complex in TA-3, built in the 1950s and 1960s, has housed extensive laboratory areas for synthesizing, processing, characterizing, and fabricating materials such as beryllium, uranium, thallium, and aluminum alloys. These activities included large-scale metallurgy and fabrication of normal and fully enriched uranium. As of 1969, the CMR Bldg, except for its Wing 9, was used for laboratory work on small quantities of uranium and plutonium. Wing 9 contained hot cells for handling irradiated uranium and sometimes plutonium (see Chapter 8).

Uses of Uranium in Explosive Testing

LANL staff estimated in 1971 that between 75,000 and 95,000 kg of uranium had been expended in experimental shots at LANL from 1949 through 1970 (Drake and Eyster, 1971). Normal uranium was used until 1954, after which time depleted uranium was used exclusively. A 1952 AEC report states that test shots at LANL routinely dispersed 300 lbs of uranium per month and 2,000 lbs of barium per month

(English, 1952). Between 1944 and 1948, eight firing sites (A-H) were established at TA-15 (R-Site). Experiments using from 50 lbs up to two tons of HE were conducted at these firing points. Firing points E and F were the most active. Up to 65,000 kg of uranium and 350 kg of beryllium were expended at these two firing sites. Hazardous materials, including uranium, beryllium and lead, were largely left in the places where they had been deposited by explosions at these sites (LANL, 1992).

The Bayo Canyon Site (TA-10) was used between 1944 and 1962 for experiments using conventional high explosives, radioactive lanthanum (RaLa), and, in some cases, depleted or natural uranium. The explosions resulted in the dispersion of uranium, ^{140}La, and ^{90}Sr in the form of aerosols and debris to the atmosphere and onto the ground.

Use of Uranium at LAMPF / LANSCE

Originally constructed to study sub-atomic particles, the Los Alamos Meson Physics facility (LAMPF) includes an accelerator that has been used to generate intense pulses of neutrons by sending protons into targets of high atomic number such as uranium.

Accidents and Incidents Involving Uranium

In addition to describing routine, operational releases of uranium, some LANL documents also describe accidents and incidents involving uranium that could have been associated with airborne and/or waterborne releases to the environment. Some of the documented accidents that that have involved uranium are summarized in Table 9-1.

Table 9-1. Some accidents and incidents at LANL involving uranium

Date	Description	Repos. No.
2/1/1951	On February 1, 1951 there was a criticality incident involving 2 cylinders of U-235. The cylinders weighted 24.4 kg and 38.5 kg of 93% U-235. The 2 cylinders were in a water reflected system. There was slight oxidation of the uranium. 10^{17} total fissions were involved.	6206
12/9/1952	On December 9, 1952 in S-104 uranium in a furnace caught fire and was contained in the furnace. Clean-up of S-104 was conducted on December 11 and 12.	3495
6/26/1953	On June 26, 1953 there was a small fire in a flask containing uranium hydride in D-151.	3491
12/5/1953	On December 5, 1953 a glass furnace in a vacuum hood exploded releasing 40g of uranium.	3491
3/9/1955	Uranium was released into the hood of Room 121 at TA-46 on March 9, 1954.	2383
5/12/1955	On May 12, 1955 a small furnace erupted releasing an unknown quantity estimated at less than one kilogram of uranium in Room 102 of Sigma Building.	2374
7/21/1955	On July 21, 1955 some normal uranium caught fire in Room 1131.	1184
8/19/1955	On August 19, 1955 an employee dropped a test tube containing one gram of normal uranium in Wing 2 of CMR Building.	3489
3/9/1956	On March 9, 1956 a spill of uranium flowed into the bottom of the furnace in Room 21 of the Sigma Building.	2383
9/27/1957	On September 27, 1957 rags contaminated with sodium and uranium caught fire in Room 133 at Ten Site. Fire was quickly extinguished with CO2.	2414
4/1/1959	During processing of irradiated U-235 at TA-48 uranium oxide was blown out of the hood when a sample can was opened.	2514
12/3/1959	On December 3, 1959, a fire broke out in the duct work of Room 313 of DP West where uranium materials are incinerated. The damage was limited to the duct work.	2494
6/17/1960	On June 17, 1960 there was a criticality incident involving ~48 kg U-235. Uranium cylinders in thick graphite (9-in.) reflected before complete assembly, resulting in trivial damage. 6×10^{16} total fissions were involved.	6206
8/7/1961	On August 7, 1961 a container with a uranium fuel element leaked. Contamination products were detected in the parking lot and around the building. No decontamination was done.	2524
4/8/1963	On April 8, 1963 there was a uranium spill at TA-46.	2536
1/10/1964	On January 10, 1964 in SM-66 depleted uranium residue ignited in a drum. The material was allowed to burn out.	2812
4/22/1964	An explosion occurred following a fire in Room 313 DP West from uranium contaminated rags on April 22, 1964. The fire spread from the drybox to the adjoining hood.	2505
6/1/1965	At DP East the gas purge line to a recovery furnace became plugged. The operator in charge removed a rubber hose connected to the unit, and uranium-containing dust was blown out into his face and onto his clothing.	NA
11/16/1966	The air cleaner at one of the enriched uranium shops developed a pin-hole leak, which resulted in high surface contamination of the surrounding area.	NA
1/15/1969	A glovebox explosion occurred in the uranium recovery operation at DP West, during the incineration of U-235 metal turnings.	NA
4/3/1970	On April 3, 1970 a furnace containing uranium exploded releasing dust in SM-35 Room 104.	4261
11/2/1971	On November 2, 1971 an explosion in test cell furnace blew uranium contamination onto floor.	1417
5/4/1979	A stainless steel pot containing uranium tritide was overheated in a laboratory at the Cryogenics Building and ruptured on May 4, 1979. tritiated water escaped into the laboratory because of inadequate air flow in the hood. Some tritium was released to the atmosphere.	4484
11/2/1982	On November 2, 1982 approximately 50-100 L of waste liquid escaped from a tank vent at TA-21-257 contaminating the building roof, walls, and surrounding area with low levels of plutonium, americium, and uranium.	NA

Evaluation of Potential Health Risks from Atmospheric Releases of Uranium

As summarized above, the main areas where uranium has been used in machining or fabrication include TA-1, TA-3, and TA-21. Considerable quantities of uranium have also been expended in firing site activities conducted at TA-15, TA-36, and others. LANL's operations have involved a wide range of uranium enrichment, from depleted (primarily ^{238}U, with very little ^{235}U) to highly enriched (primarily ^{235}U).

Figure 9-1 shows LANL's reported airborne releases of uranium from routine operations for the period 1952 through 1995. The release data have been adjusted upward through application of correction factors for sample line losses and for degraded counting efficiency due to dust loading and burial in the sampling media. These correction factors are discussed further in Chapter 17. "Routine operations" has been used here to differentiate between chronic releases associated with everyday activities and episodic releases associated with dynamic testing. The routine releases were those from elevated stacks or roof vents. The principal sources of routine airborne releases of uranium reported by LANL were TA-3 and TA-21.

No uranium-specific release data have been identified to date for the period prior to 1952. Uranium releases from TA-21 are not reported prior to 1962, meaning the uranium source term for 1952 – 1961 is underreported unless there were no releases from TA-21 during that period. Uranium release data for TA-3 are also currently unavailable for the period 1962 – 1966, so the source term for that period is likewise understated. There are airborne effluent data available from earlier in LANL's history, however, the data are not nuclide specific. Rather, they are reported in terms of gross beta and gross alpha activity. Specifying the reported gross beta and gross alpha releases in terms of their nuclide-specific constituents is beyond the scope of this initial investigation.

Figure 9-1. Routine airborne releases of uranium from LANL 1952 – 1995

To gauge what impact LANL's atmospheric uranium releases may have had in terms of human health risk, the NCRP Report No. 123 screening model (NCRP, 1996) was applied to airborne uranium source term information for TA-21. TA-21 was selected because it was the largest source of airborne releases of uranium reported by LANL for its routine (i.e. non-firing site) operations. The screening was performed using the data for 1963, the year of the largest release reported by LANL.

The 1963 uranium release was screened against a criterion of a 1 in 100,000 added risk of fatal or non-fatal cancer, assuming a risk factor of 5.5% per sievert (Sv) (ICRP, 2007). This figure corresponds to a dose equivalent of 1.82×10^{-04} Sv (18.2 mrem). The exposed population selected was the residential area nearest the release point. In the case of TA-21this was the Group 18 residential area, just west of the airport. The distance between this area and the uranium release points from TA-21 was estimated to be 540 m. The pathways considered were inhalation of contaminated air, plume immersion, irradiation from contaminated ground, and consumption of contaminated soil and vegetables. Consumption of locally-raised meat or milk was not considered. The applicable NCRP 123 screening factors for the selected

pathways were 0.31 Sv per Bq per m^3 and 0.33 Sv per Bq per m^3 for ^{234}U and ^{235}U, respectively. Inhalation is the dominant contributor to both factors, being 93% of the total for ^{234}U and 80% for ^{235}U. For simplicity, the release was screened as 100% ^{235}U. A bounding value for the air diffusion factor was selected based on the source-receiver difference. This value was conservative, and avoided the need to account for effective release height and building wake effects.

The NCRP Report No. 123 screening evaluation for the 1963 airborne uranium release from TA-21 gave a screening value of 6.94×10^{-4} Sv (69.4 mrem). This value is larger than the screening criterion, indicating that further investigation of uranium releases from DP Site is warranted.

A screening calculation was also performed for uranium releases from TA-3 using the same method as for the TA-21 release. For TA-3 the maximum reported release occurred in 1956, and the distance to the nearest residential area (the Western Area) was approximately 1,100 m. The resulting screening value was 2.47×10^{-5} Sv. This value is smaller than the screening criterion on its own, however, NCRP 123 recommends dividing the criterion by 10 to account for uncertainties. Doing so gives an adjusted screening criterion of 1.82×10^{-5} Sv, which is smaller than the calculated screening value. Thus, further investigation of uranium releases from TA-3 is also warranted.

Radioactive Lanthanum (RaLa) Operations

Barium/lanthanum is a mixture of ^{140}Ba and its daughter product ^{140}La . ^{140}La was the isotope used by LANL in the years between 1944 and 1962 as an aid in "hydrodynamic tests" conducted primarily to perfect the implosion process. ^{140}La has a 40-h half-life, a strong gamma emission, and "grew into" the ^{140}Ba that was produced in large quantities in the Clinton Pile at X-10 Site in Oak Ridge (Widner, 2000, Widner and Flack, 2002) and later at the Idaho National Engineering Laboratory. RaLa was used in implosion testing from September 21, 1944 through March 6, 1962 (Dummer et al., 1996). All RaLa implosion tests were conducted in Bayo Canyon (TA-10), shown in Fig. 9-1. Fig. 9-2 depicts the location of the buildings and firing points within TA-10.

Fig. 9-2 . Bayo Canyon Site, TA-10, in 1950. View is toward the west.
Photo ERID-018982 courtesy of LANL

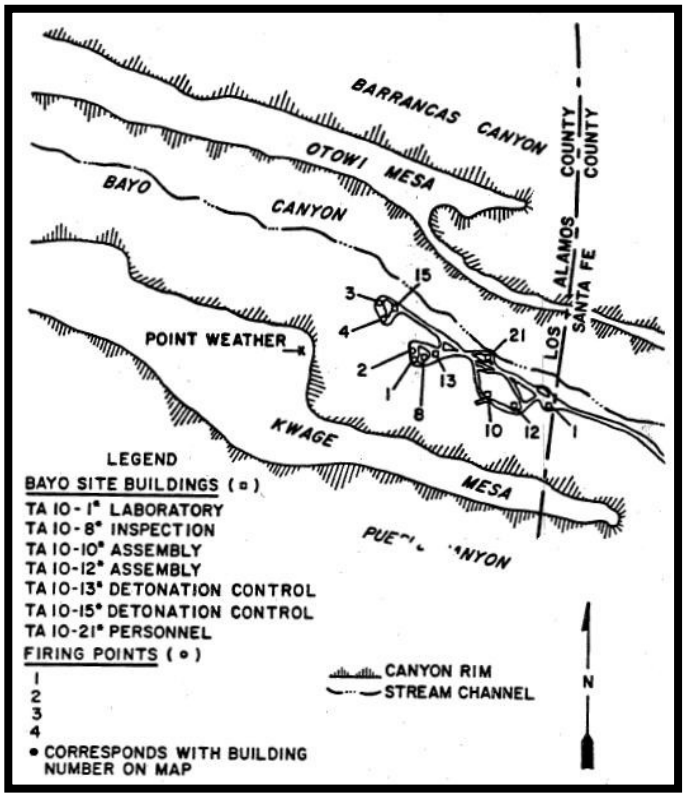

Fig. 9-3. Layout of TA-10, Bayo Canyon

From 1944 to 1950, the RaLa sources were prepared at the TA-10 Chemical Processing Building. Preparation of the RaLa sources was moved to TA-35 ("Ten Site") for the period of 1951 through 1963, and operated by group CMR-10. The ^{140}La sources were placed in shielded containers and trucked to the firing site, where they were remotely loaded to the explosive test assemblies.

In order to obtain data on implosions, LANL personnel had previously conceived a procedure of placing a gamma ray source at the center of a spherical implosion assembly. The emitted gamma rays would travel outward radially, through both the collapsing shell and the high explosive. The increased compression of the metallic shell during implosion would cause the gamma rays to be increasingly absorbed. The gamma rays were monitored by detectors set around the high explosives. The monitored data would provide data on the density changes in the collapsing shell, the time of collapse, and the degrees of compression and symmetry by comparing the gamma rays' intensity in different directions. A mixture of ^{140}Ba and ^{140}La were to be used as the gamma ray source. Because of potential post-experiment radioactive problems, however, ^{140}Ba was removed from the mixture.

^{140}La was initially provided by Oak Ridge as a mixture of ^{140}Ba and ^{140}La. Chemists at the TA-10 Chemical Process Building prepared RaLa sources by separating a solution containing the parent ^{140}Ba and other impurities, such as ^{89}Sr and ^{90}Sr. The separated RaLa, along with unavoidable small amount of barium and strontium, was then encapsulated as specified by each experiment—sometimes in a metal sphere no larger than a match head (a pure 1,000-Ci ^{140}La source weighs 0.8 mg).

The explosive test assemblies used surrogate materials with mechanical properties similar to plutonium. Uranium, although used, had the disadvantage of being a strong gamma-ray absorber. Metals such as iron, copper, or cadmium were used, and most of the early shots employed cadmium (Dummer et al., 1996). The implosion assembly was surrounded initially by a number of ionization chambers (see Fig. 9-4) and later by scintillation detectors.

Fig. 9-4. Ionization chambers surrounding a RaLa shot on May 13, 1947

Table 9-2 lists, by year, the number of test shots and the amount of RaLa involved. A total of 254 tests were conducted between 1944 and 1962, with RaLa sources ranging in size from about 25 Ci to 7,090 Ci. The explosions resulted in the dispersion of the metallic shell (uranium or other material, such as cadmium) and the radioactive RaLa and residual impurities such as ^{140}Ba and ^{90}Sr, in the form of aerosols and debris to the atmosphere and onto the ground.

The preparation of the RaLa conducted at TA-10 generated liquid and radioactive wastes that were disposed of in subsurface pits and leaching fields at the site. Almost two million curies of ^{140}Ba had been handled at TA-10 and TA-35 by the time the RaLa program was terminated in 1963. The TA-10 site was decommissioned by 1963 and transferred to Los Alamos County on July 1, 1967 (Mayfield et al., 1979). In addition to = RaLa, about 226 mCi of Strontium-90 was reportedly released; over 80% of the 226 mCi was released in seven shots in 1945 (Dummer et al., 1996). In a dose assessment conducted by LANL personnel, the highest annual dose from the RaLa shots (17 mrem) was calculated to have occurred in 1955. The calculated dose for those who were in Los Alamos during the experiments ranges from 110 mrem to 450 mrem (Mayfield et al., 1979, Dummer et al., 1996, Kraig, 1997). None of these dose assessments have been independently critiqued by the LAHDRA team.

Table 9-2. Annual quantities of radioactive lanthanum used in RaLa shots at Bayo Canyon

Year	Quantity of RaLa Used (Ci)	Number of Shots
1944	1,112	10
1945	18,363	36
1946	20,556	24
1947	22,734	27
1948	12,236	19
1949	28,255	26
1950	19,788	12
1951	0	0
1952	6,370	4
1953	1,065	4
1954	15,580	13
1955	40,763	21
1956	35,976	21
1957	17,358	9
1958	9,845	7
1959	8,322	8
1960	5,560	5
1961	24,312	5
1962	13,607	3
Totals	301,802	254

During March and early April, 1950, the Air Force sought to conduct independent studies of airborne radioactivity (Dummer et al., 1996). It selected three of the 254 RaLa experiments (Shots 147, 148, and 149), and used a B-17 aircraft to track and measure radioactivity in the resulting cloud. In July, 1950, LANL provided the Air Force with a static 400 Ci RaLa source for additional analysis. The source was transported to an area near Abiquiu, about 22 air miles north of Los Alamos, and seven passes were made by an airplane over the stationary source (Dummer et al., 1996).

Polonium Operations

Polonium was used in atomic bomb initiators, utilizing the (α,n) reaction of ^{210}Po and ^{9}Be to generate neutrons. In February, 1945, schedule for polonium delivery from Monsanto to the Original Technical Area was increased to 100 Ci per month by June, and to 500 Ci per month by December (Hoddeson et al., 2004). At TA-1, polonium was handled in D-Building, H-Building, and Gamma Building. DP East Site

began operation in September, 1945 and contained Buildings 151, 152, and 153. Building 155 was completed in December, 1949. Reports indicated that "the well-designed DP polonium plant went into operation sooner than did the plutonium plant" (DP West site; TR 6704, Box 6 of 8). The DP East Site facilities were used to process polonium and actinium and to produce initiators.

At DP East, Building 21-153 exhausted air from the main buildings at DP East, was constructed similarly to Building 12, and was in service until March, 1970. The primary radioactive contaminant of this filter house was ^{227}Ac. Bldg. 153 had transitional plenums and filter housings for electromatic filters, two blowers, and two stacks. Stack monitoring data for DP East Site have been located in CMR-12 monthly progress reports starting in August, 1945. The data are presented as average counts per minute per liter over each month for DP East Stack 1 and Stack 2. These data are for alpha-emitting radioactivity, with no isotopic composition indicated through at least 1949.

Polonium was also expended in explosive testing at LANL. TA-33 (Hot Point or HP) Site, for example, was developed in 1947 for LANL's weapons testing group as a substitute test site for experiments being conducted at Trinity Site in southern New Mexico (McLain et al., 2001). These tests used conventional high explosives as well as uranium, beryllium, and polonium radiation sources. Experiments conducted primarily to verify nuclear weapon initiator designs were performed in underground chambers and on surface firing pads. Additional tests were carried out at TA-33 firing sites equipped with large guns that fired projectiles into earthen berms. The documents associated with LAHDRA Repository Numbers 2375, 4519, 6523, and 7021 provide details of events at TA-33 that resulted in releases of polonium from tests at TA-33 in the 1950s.

On January 8, 1953, a mock fission source containing polonium and beryllium ruptured at Pajarito Site (TA-18) and the resulting contamination spread to the housing area (Shipman, 1953). Possibly as much as 2 Ci of polonium was lost, the greater part of which was thought to have remained in and around LANL at Pajarito Site. However, "significant amounts [of polonium] were found in a number of homes." Among the items found to be contaminated in a "large number" of homes were shoes, clothing, floor coverings, vacuum cleaners, children's toys, and baby diapers. Rugs and upholstered furniture presented serious decontamination problems.

On August 3, 1955, a Po:Be neutron source ruptured, resulting in the contamination of 150 staff members in Building SM-40 (Shipman, 1955). A mock fission polonium source containing 25.2 Ci of polonium exploded in the basement of the Physics Building, and contamination was spread throughout the building. It was five days or more before most personnel could return to work. Air samples for the area reportedly

never exceeded "3 times tolerance." Although reports indicated that no activity reached homes or personal vehicles, a "few" government vehicles were contaminated.

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Chapter 10: The Trinity Test

During the first six months of development work at LANL, the focus of the ordnance program was the gun method of assembly. Up until August, 1944, the plutonium gun was the main focus of activity. By August, 1944, the high velocity uranium gun had been thoroughly proved in principle, but the plutonium gun assembly program was abandoned. LANL's main efforts were now directed to the mounting difficulties of the implosion program. The proposal for implosion assembly required using a plastic flow tamper and active material under high-explosive impact. The first advantage of the implosion weapon over the gun weapon was its much shorter assembly time, especially important since plutonium's expected high neutron background makes predetonation a serious danger (Hawkins, 1961). The implosion-assembled, plutonium-based design[i] was far more complicated than the gun-assembled design. A test of that device was considered necessary because of the "enormous step" of moving from theory and experimentation to producing a combat weapon and realizing that, if the device failed over enemy territory, "the surprise factor would be lost and the enemy would be presented with a large amount of active material in recoverable form."[ii]

Document Review

Internal LANL technical reports (many with LA- and LAMS- prefixes) in the LANL Reports Collection and the document holdings of the LANL Records Center and Archives were the primary sources of information about the implosion weapon development and the Trinity test program. These collections were reviewed, and copies of relevant documents were requested for public release. Information from interviews with Trinity participants, Web sites, the Nuclear Testing Archives in Las Vegas, news archives, and books available from the popular press were also incorporated into this information summary regarding the Trinity test.

Preparations for the Test

Test Organization

Testing the implosion bomb was considered essential by LANL's director and most of its group and division leaders. The first test preparations were made in March, 1944, when Group X-2 was formed in the Explosives Division, headed by George Kistiakowsky. The duties of the X-2 group under Kenneth

[i] Implosion-assembled weapons were designed on the principle of compressing the fissile material to super-criticality by detonating a high-explosive implosion system.
[ii] "The July 16, 1945 Trinity Bomb Test," September, 1945. LANL Archives Collection A-1984-019.

Bainbridge included preparing for a field test in which blast, earth shock, neutron, and gamma radiations would be studied, and complete photographic records would be taken of the explosion and any associated atmospheric phenomena. This work was initially set up under Section X-2C, with L. Fussell, Jr. in charge.

In May, 1945, a temporary organization was formed consisting of seven groups designated TR-1 through TR-7 ("TR" for Trinity). Organizationally, the test was called Project TR, and, for reasons of secrecy, the test site was referred to as "T Site" prior to the test. Personnel from R, G, O, F, and X Divisions and military personnel from the SED (Special Engineering Detachment) were reassigned to this "division" until the test was completed (Bainbridge, 1976). Project Trinity was led by K. T. Bainbridge, with Frank Oppenheimer (brother of J. Robert Oppenheimer) serving as his aide. Responsibilities of the TR groups were as follows:

- TR-1, headed by John H. Williams:
  construction, procurement, transportation, timing, communications
- TR-2, headed by J. H. Manley:
  measurements of air blast and earth shock
- TR-3, headed by R. R. Wilson:
  physics measurements: prompt alpha, delayed neutron and gamma radiation
- TR-4, headed by J. M. Hubbard:
  meteorology
- TR-5, headed by J. E. Mack:
  spectrographic and photographic measurements
- TR-6, headed by B. Waldman:
  air blast airborne measurements
- TR-7, headed by L. H. Hempelmann:
  medical, including instruments, the monitoring group, and first aid
- Special Assignments:
  four searchlight crews, an announcer, and weather advisers

J. Robert Oppenheimer and George Kistiakowsky stated in a 1944 memo that "if we do not have accurate test data from Trinity, the planning of the use of the gadget over the enemy territory will have to be done substantially blindly" (Jones, 1985).

Site Selection and Construction

Bainbridge's group considered eight sites[i] for testing the first implosion weapon— three in New Mexico, two in California, one in Texas, and one in Colorado. The LANL scientists established the following criteria for the site:

- flat terrain to minimize effects of the blast, and to facilitate easy construction of roads and communication lines;
- sufficient distance from populated areas, but close enough to Los Alamos to minimize travel between the two sites;
- clear and sunny weather on average to permit the extensive collection of optical data; and
- convenience to good rail transportation.

The Manhattan Project's military head, Major General Leslie R. Groves, added further conditions, requiring that the area be about 17 by 24 mi in size, and that it house no Native Americans; this requirement was made primarily so that General Groves would not have to deal with Secretary of the Interior Harold Ickes, whom he thought would cause difficulties (Groves, 1962). General Groves made the final site selection in late August, 1944. When Groves discovered that, in order to use a California location that he favored, he would need the permission of its commander, General George Patton, Groves quickly decided on his second choice, the *Jornada del Muerto*[ii] (Journey of Death) valley, for the main reason that General Groves did not want anything to do with the flamboyant Patton, whom Groves had once described as "the most disagreeable man [he] had ever met" (Szasz, 1984).

Bainbridge, a Harvard physicist assigned by J. Robert Oppenheimer to oversee the bomb test and base camp preparations, selected the 18- by 24-mi tract of land in the northwest corner of the *Jornada del Muerto* valley east of the Rio Grande in the New Mexico desert (Bainbridge, 1976, Jones, 1985). As soon as the Air Force's commanding general for the New Mexico district approved Bainbridge's request to have a section of the Alamogordo Bombing and Gunnery Range turned over to the Manhattan Project, Bainbridge called Oppenheimer to tell him the good news, and urged him to pick a code name for the site as soon as possible. Oppenheimer was familiar with a book of John Donne's poems, and the opening line of one he recalled was: "Batter my heart, three-person'd God; for, you as yet but knock, breathe, shine,

[i] Besides the Jornada del Muerto, the other sites in New Mexico were the Tularosa Basin near Alamogordo, the lava beds (now the El Malpais National Monument) south of Grants, and an area southwest of Cuba and north of Thoreau. Possible sites outside New Mexico were: an Army training area north of Blythe, California, in the Mojave Desert; San Nicolas Island (one of the Channel Islands) off the coast of Southern California; on Padre Island south of Corpus Christi, Texas, in the Gulf of Mexico; and in the San Luis Valley of south central Colorado, near today's Great Sand Dunes National Monument (USDOE 1994).

[ii] This area was a short cut on the Camino Real, the King's Highway that linked Mexico to Santa Fe, used to avoid a valley that was too narrow for supply wagons. Sixty mi of desert, with very little water and numerous hostile Apaches, led the Spanish conquerors of New Mexico to assign the name.

and seek to mend..." One theory is that Oppenheimer said "we'll call it Trinity" based on that poem (Lamont, 1965).

Another theory, however, is that Oppenheimer selected the name with reference to the divine Hindu trinity of Brahma (the Creator), Vishnu (the Preserver), and Shiva (the Destroyer). Oppenheimer had an avid interest in Sanskrit literature (which he had taught himself to read), and, following the Trinity test, reportedly recited a passage from the Bhagavad-Gita (Radiochemistry Society, 2007).

A great deal of time was initially wasted in land surveys because of inadequate maps. Maps were requested through the Security Office in June, 1944, but many were never received. The maps that were eventually used were obtained by ordering all the geodetic survey maps and most of the grazing service and county maps for the state of New Mexico; aerial mosaics and land status maps had to be "scrounged." Aerial photographs of the northwest corner of the Alamogordo Air Base were obtained from the Air Force and assembled into a photo mosaic that was used with a transparent overlay to determine locations for the main instrument shelters that would not be in washes. The selected land tract permitted separation from nearest habitation by a minimum of 12 mi to the north and west. Moreover, the government controlled the land out to 18 mi on the east. The nearest towns in any direction were 27-30 mi away, and the prevalent winds were from the west (Bainbridge, 1976). A memorandum justifying the construction and equipment requirements for the proposed scientific measurements was given to Oppenheimer in October, 1944. A construction company contracted by the Army [J. D. Leftwich Company of El Paso, TX] completed the first camp facilities by the end of December, 1944, and a small military police detachment under Lt. Bush arrived from LANL to provide site security (Bainbridge, 1976). Shortly after, a much larger group of scientists, technicians, medics, civil service personnel, and construction workers arrived.

At the new site, a maze of roads needed to be built, hundreds of mi of wire had to be strung over and under the ground, a complete communication system had to be installed, buildings had to be erected, supplies, equipment, and personnel had to be transported between Los Alamos and Trinity, and all these tasks had to be completed under the cloak of extreme secrecy (LASL, 1979). By early 1945, there were more than 200 residents of the Trinity Base Camp. Civilian construction crews aided by construction personnel from LANL built additional facilities in the spring of 1945 to ready the site for the bomb test, which was scheduled for early summer (Jones, 1985).

Fig. 10-1 through Fig. 10-3, facilities at the test site included:

- A Shot Tower (located at "Ground Zero," the central reference point)
- Base Camp (located ten mi to the south-southwest)
- South Shelter (located 10,000 yd (about six mi) to the south; housed VIPs and the control center for the test)
- North Shelter (located 10,000 yd to the north; housed personnel, instruments, and searchlight crews)
- West Shelter (located 10,000 yd to the west; housed personnel, cameras, and searchlight crews)

The three shelters, which were heavily-built wooden bunkers reinforced with concrete and covered with earth, were code named Able, Baker, and Pittsburgh (National Atomic Museum, 2007). Test personnel made use of the McDonald Ranch House for final assembly of the bomb's plutonium core. Trinity Base Camp included stables, a blacksmith shop, water storage tanks, a hay barn, officers' quarters, a supply room, mess hall, barracks, latrine, P.X. and day room, coal storage, infirmary, laboratory, technical warehouse, office, garage, gasoline storage tanks, fire station, engineering office, plumbing shop, electrical shop, carpentry shop, and drinking water tanks (Merlan, 2001).

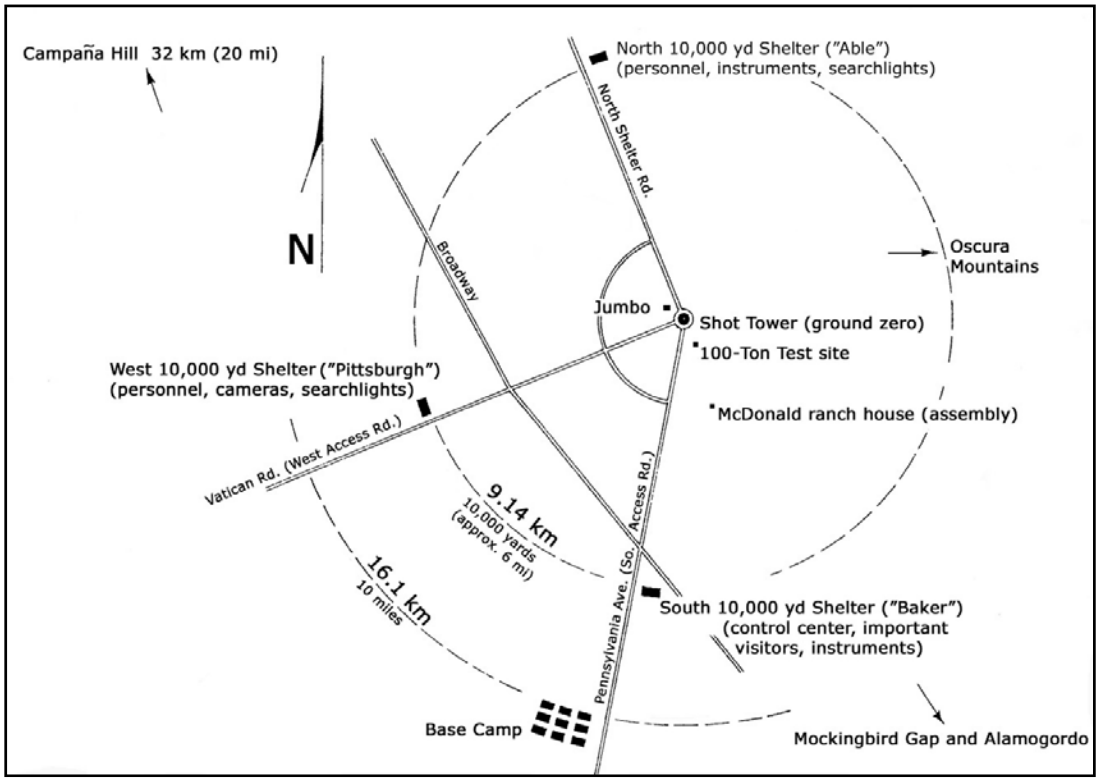

Fig. 10-1. Map of facilities at the Trinity Test Site (based on Lamont, 1965)

The 100-Ton Test

In the summer of 1944, a "100-ton test shot" using conventional high explosives (HE) was proposed in order to calibrate the blast and earth shock measuring equipment at the Trinity site, and to serve as a dress rehearsal for the summer, 1945 test. The "first" Trinity test occurred on May 7, 1945 at the New Mexico site 800 yd south of what would be ground zero for the July 16 test. It was the first chance to test experimental data under explosion conditions. Since explosions of more than a few tons of TNT have different characteristics than lesser amounts, 108 tons of HE (Composition B, a mixture of TNT and the explosive RDX) brought in from Fort Wingate[i] and a small volume of radioactive solution (to simulate the radioactive products of the nuclear test) were detonated atop a 20-foot platform (Fig. 10-4), so that dispersion could be characterized and instruments could be calibrated (LASL, 1979, Jones, 1985, Radiochemistry Society, 2007).

[i] Erickson (1946) described the explosive charge for the 100-Ton Test as 3590 wooden boxes (179,500 lbs) of flaked TNT and 744 boxes (32,044 lbs) of pelletized Composition B.

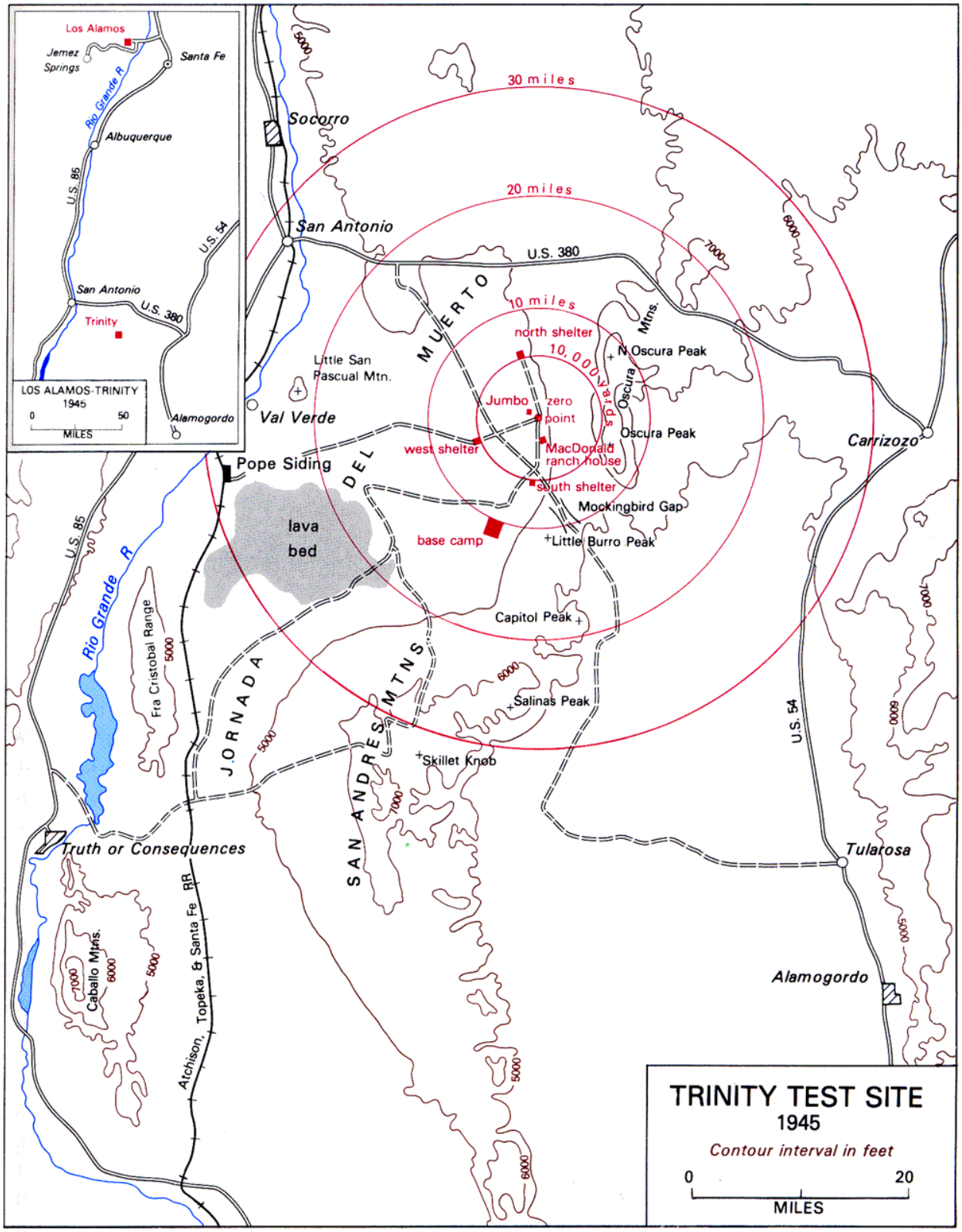

Fig. 10-2. Location of the Trinity Test Site and nearby towns (from Jones, 1985)

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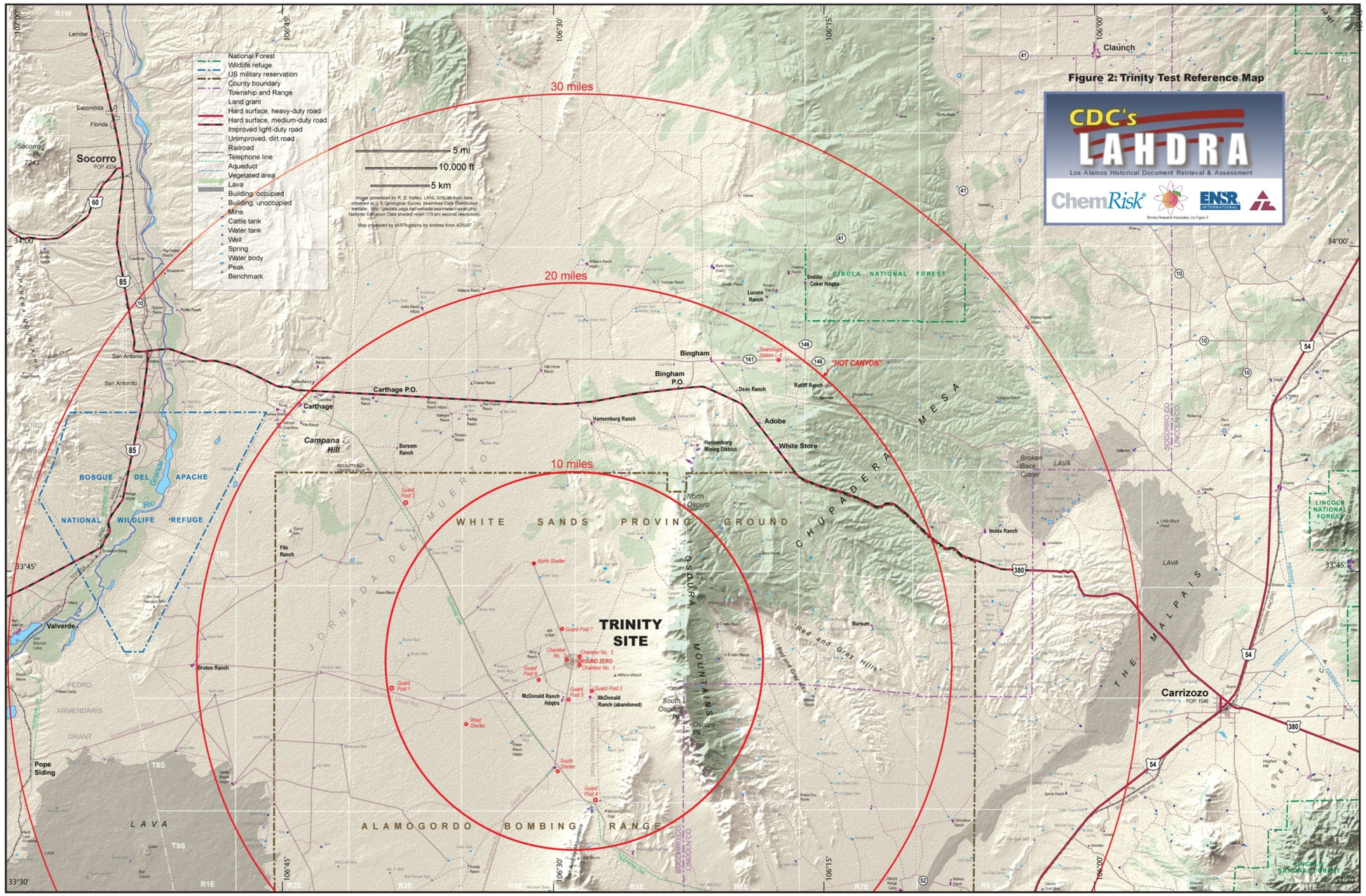


Fig. 10-3. Map of Trinity Site within White Sands Proving Ground, Nearby Towns, and Terrain Features

Back of Fig. 10-3 -- 11×17 sheet

Box after wooden box of HE were stacked until approximately 100 tons were in the pile. An irradiated uranium fuel slug from a Hanford reactor was dissolved using the apparatus shown in Fig. 10-5 and poured into flexible tubing threaded through the high explosive (Sugarman, 1945). The solution introduced into the pile had beta activity of 1,000 Ci and gamma activity of 400 Ci.

Fig. 10-4. Boxes of high explosives stacked for the "100-Ton Test"

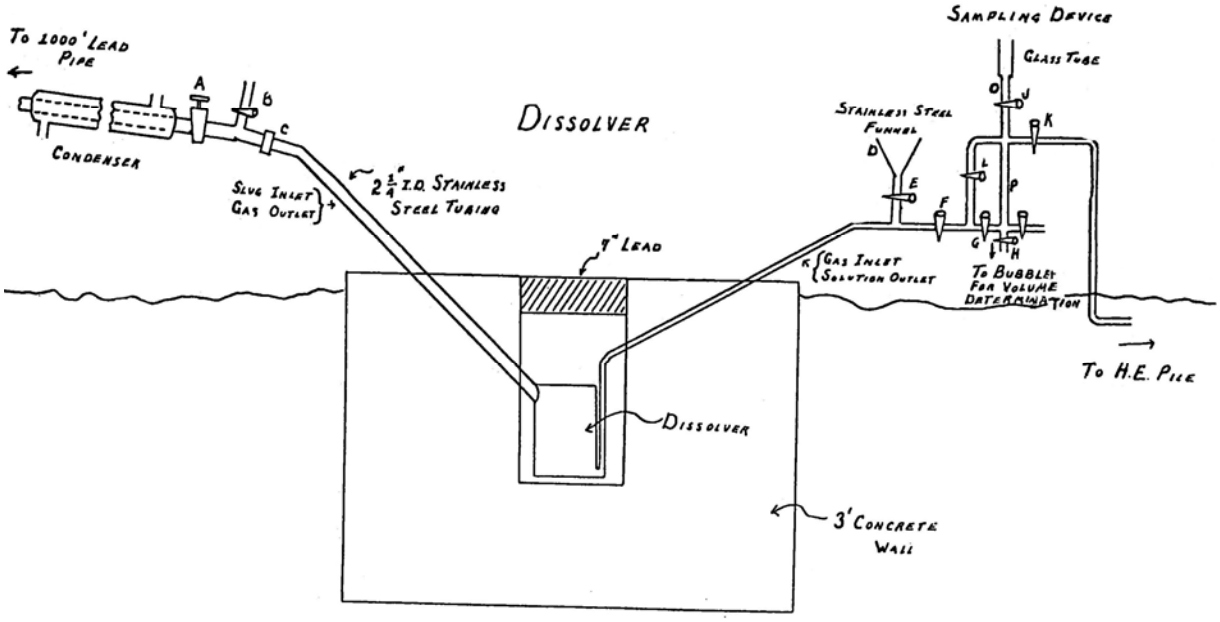


Fig. 10-5. Diagram of the equipment used to dissolve an irradiated uranium fuel slug from a Hanford reactor for dispersion in the 100-Ton Test at Trinity Site (Sugarman, 1945). The fuel slug entered the dissolver via the pipe from the left, by which off-gases were also exhausted. The radioactive solution exited via the tubing to the right, into the stack of boxed high explosives.

The blast (Fig. 10-6) compressed and blew the surrounding earth into a saucer-shaped crater, expelling about 40% of the dirt. A scaling up the RaLa shots suggested that 10% of the activity would remain in the soil within a 300-ft radius. However, only 2% of the activity of the dissolved radioactive material was deposited in the crater out to a distance of 450 ft from the center, indicating that simple scaling did not account for the increase in updraft with increased explosive charge.

According to Richard C. Tolman, a physicist who served as an advisor to General Groves, the explosion of the "100-ton test" aroused little comment in neighboring towns, but the illumination and sound were detected at the Alamogordo Air Base 60 mi away by a pre-warned observer. According to Hempelmann, the level of activity after the blast in the crater was low enough to be safe for several hours of exposure. The dissolving unit was covered with dirt and surrounded by a guard fence. After this explosion, suggestions for improving the facilities and procedures included paved roads to protect personnel and instruments from dust, more vehicles, more vehicle repairmen, and more telephone lines (Bainbridge, 1976, Hoddeson et al., 1993).

Fig. 10-6. Views of the "100-Ton Test" blast at 1, 2, and 3 seconds after detonation.
(photos obtained at nuclearweaponarchive.org/Usa/Tests/Trinity.html)

Date Selection and Meteorology

July 4 was the original target date for the second test at Trinity, which was to be the nuclear test. In mid-June, Oppenheimer said that July 13 was the earliest possible date for the test; however, LANL's "Cowpuncher Committee" had primary responsibility for coordinating and scheduling Trinity. The committee was composed of S. K. Allison, former Director of the Metallurgical Laboratory, Kistiakowsky, Captain Parsons, C. C. Lauritsen, Bacher, and Hartley Rowe, a former Technical Advisor to General Eisenhower. It was organized "to ride herd" on the implosion program.

After reviewing developments on June 30, the committee advanced the test date to July 16 in order to include certain additional vital experiments. The committee held its first meeting in early March, 1945.

This group met often, and published a semi-monthly report called "The Los Alamos Implosion Program" that presented in detail the current status of the work. Since Secretary of War Henry Stimson would be attending the Potsdam Conference starting on July 16, General Groves requested a test date of July 14 so that the results of the test would be known before that date. The bomb test team, however, insisted on a test date of July 17. On July 7, Oppenheimer told Groves the test could take place on the 16th, but no earlier, since all parts of the Gadget (the code name for the Fat Man implosion bomb) would not be ready before July 16 (Jones, 1985).

The date of the Trinity test depended on the availability of components, as well as on the weather. Haze, dust, and mirage effects would interfere with photographic measurements. Overcast skies would make flying more difficult for the airplanes needing to drop instruments. Winds had to be favorable to keep the radioactive cloud away from inhabited areas to the east and north. Each group was asked to specify the best weather conditions for its experiment, and meteorologist Jack Hubbard tried to find a date to match all the requirements. Hubbard initially projected that the best dates for the Trinity test would be between July 18 and 21, with July 12 through 14 as second best. The preferred time was several hours before dawn (Hoddeson et al., 1993).

Meeting the weather needs of all groups proved impossible, and the groups had to compromise. Optimum winds would draw the radioactive cloud away from the nearby towns and break it up rapidly. Winds from the northwest through southwest were judged best, and were typically the driest, thereby keeping thunderstorms from washing additional radioactivity down to the earth's surface. No one was sure how high the radioactive cloud would go. An inversion layer over nearby towns, which were 27-30 mi away, would prevent material from touching down in those areas. Although thunderstorms were expected for July 16, Hubbard agreed that the shot could be made, even if conditions would not be optimal for all the planned experiments (Hoddeson et al., 1993).

Scheduling Impacts on Planning of Protective Actions

After the date for the Trinity test was set as July 16, 1945, Dr. Louis Hempelmann recalled that "there was feverish activity on our part to make the town monitoring program flexible enough to adapt itself to whatever wind conditions prevailed when the test was ready" (Hacker, 1987). Anticipating that the people living in towns and on ranches in the immediate vicinity might have to be evacuated to avoid radioactive fallout, army intelligence agents led by Maj. T. O. Palmer searched the countryside trying to locate, list, and map every person living within a 40-mi radius of ground zero in case evacuation became necessary (Hoffman, 1947, Bainbridge, 1976, Hacker, 1987). The Army stationed a detachment of 160 enlisted men with vehicles at Socorro and other strategic points along main highways a few mi north of

the site. The Army also detailed 25 Counterintelligence Corps (CIC) members to towns and cities up to 100 mi from the site, with instructions to summon evacuation troops if they were needed, and to help manage public reaction to the blast (Jones, 1985).

Instrumentation, Experiments, and Cameras Put into Place

At a conference in Oppenheimer's office on December 23, 1944, diagnostic experiments for the Trinity test were categorized as essential, desirable, or unnecessary. Essential experiments include the pressure of the blast wave and the time spread in the firing of the detonators. Desirable experiments included photographic and spectrographic analyses of the fire ball, and measurement of the earth's motion during the explosion in case any lawsuits were brought against LANL for blast damage. All other experiments were deemed unnecessary (Hoddeson et al., 1993).

Much emphasis was placed on measuring the energy in the blast wave. This measurement was achieved by using a pair of beryllium-copper diaphragm microphones to record the peak pressure following the explosion, since it has been suggested that the change in pressure generated by the blast wave was the only quantity that could be measured accurately from 20 mi away during combat use. A more sophisticated method was also used, entailing precisely measuring the velocity of sound at the site of explosion and comparing it to the velocity of the blast wave. Spring-loaded piston gauges, water-filled pistons, diaphragm box gauges, and ball and cylinder gauges were calibrated to record a range of peak pressures from the blast. The mechanical gauges were insensitive to electrical disturbances, and acted as backup to the electrical methods (Hoddeson et al., 1993).

Plans were made to estimate the energy of the bomb in several ways, including determining the number of fissions by measuring the number and intensity of the gamma rays emitted. Prompt and delayed gamma rays could be measured separately. Ionization chambers were used to measure the prompt gamma rays. The ionization from the delayed gamma rays was measured by "suitable devices" placed within 10 or 20 mi of the gadget. The number and energy of the gamma rays could be used to derive the number of fissions and to calculate the efficiency and yield of the bomb (Hoddeson et al., 1993).

The energies and distribution of neutrons from the blast provided another method for calculating yield, but they were difficult to measure, since they were more likely to be degraded or absorbed. Plans were made to measure time-integrated neutron flux using gold foils in protective tubes placed between 300 and 1000 m from ground zero that would be activated by slow neutrons from the blast. Arrangements were also made to directly examine the soil from the area near the blast for plutonium and fission products to

help estimate the efficiency of the explosion. Two lead-lined tanks (Fig. 10-7) with trap doors on their undersides were equipped to recover soil samples from the Trinity site crater (Hoddeson et al., 1993).

Another essential measurement was the time interval between the high explosive detonation and the beginning of the chain reaction to determine if the nuclear reaction was started by the initiator or if it began prematurely. The degree of simultaneity of the detonators needed for an efficient implosion was unknown at the time. The presence of an informer switch at each detonator superseded the requirement for the test to be an exact duplicate of the gadget as it would be used in combat (Hoddeson et al., 1993).

A variety of instruments were put into place to measure earth motion, including the change in position of stakes, geophones, and seismographs. Seismograph measurements were made on site at the North Shelter (10,000 yards from ground zero), at Base Camp, and off site at Tularosa, Carrizozo, and San Antonio (Hoddeson et al., 1993).

Fig. 10-7. One of two lead-lined tanks prepared to recover soil samples from near ground zero

The primary purpose of the photography effort was to provide a photographic record for spectrographic and yield analysis. Different stages of the explosion required different film speeds, lenses, and exposures, and no one knew the amount or kind of light that would be emitted during the explosion. Fastax cameras taking 10,000 frames per second were put into place to record minute details of the beginning of the explosion. Fastax cameras placed 800 yd from the blast were protected by a steel and glass bunker, and were mounted on a sled that could be pulled out of the contaminated area by a chain attached to one of the lead-lined tanks; they would exhaust their film supplies in several hundredths of a second. Rotating-drum spectrograph cameras were positioned to monitor light wavelengths emitted by the fire ball, and pinhole cameras were put into place to record gamma rays. The only available well-exposed color photograph of

the explosion was taken by Jack Aeby, a 21-year old LANL scientist and amateur photographer (Hoddeson et al., 1993) using his own camera, which Italian physicist Emilio Segre had secured permission for him to carry on site to record the activities of Segre's group as they studied delayed gamma rays (Savage and Storm, 1965).

The "Jumbo" Containment Vessel

In the winter and spring of 1944, consideration was given to constructing a large pressure vessel, referred to as Jumbo, to contain the rare and valuable plutonium if the first atomic bomb turned out to be a dud. Other recovery methods considered included a below-ground sand cone (sand to high explosive weight ratio 15,000:1) and a cylindrical tank of water (water to high explosive weight ratio 50:1 or 100:1). Although a container could possibly allow scientists to recover the plutonium, all proposed blast, earth shock, and optical measurements would be rendered useless by the presence of the vessel, so this idea was not popular with the scientists. The final design for Jumbo was a 25 ft by 12 ft cylinder weight 214 tons with hemispherical ends. It was built by Babcock and Wilcox Corporation in Barberton, Ohio and shipped in early April, 1945 on a specially fabricated railcar to a railroad siding at Pope, New Mexico (
Fig. 10-8). A 64-wheeled trailer pulled by two tractors was used to move the vessel the 25 mi from Pope to the test site (Jones, 1985). By March, 1945, all recovery methods were abandoned because sufficient plutonium for a second test would be available from Hanford, and Jumbo was never used. However, it was erected 800 yards from ground zero in case it was needed for a second test (Hoddeson et al., 1993).

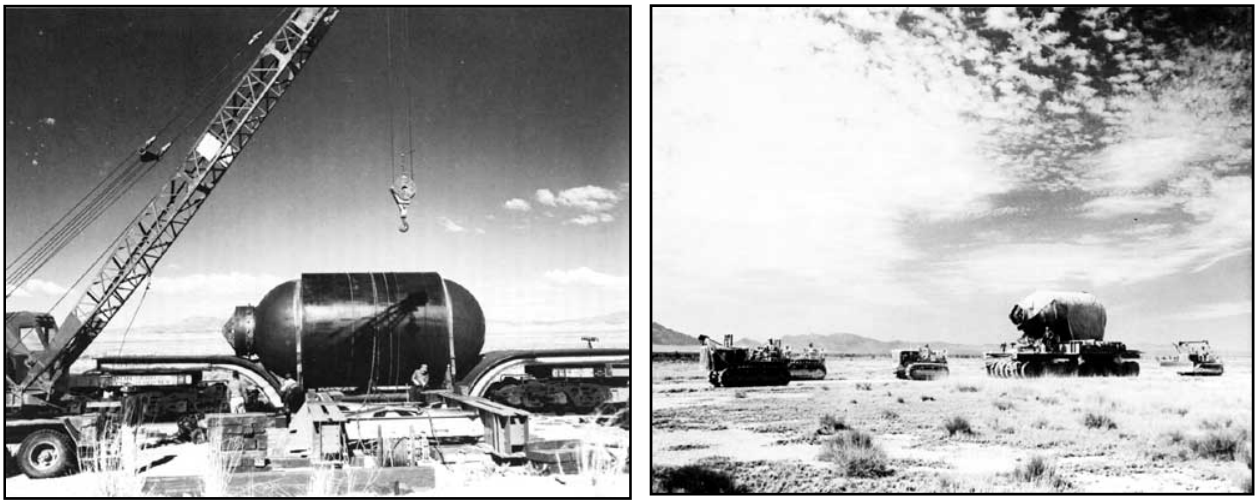


Fig. 10-8. The "Jumbo" containment vessel being loaded on a specially made, 64-wheel trailer at the Pope, NM railroad siding (left) and making its 25-mi trip to the Trinity site on a road constructed for that purpose (right).

Final Preparations

Two complete sets of high explosive castings were available on July 10. Prior to July 7, there had not been enough lens castings to make a complete charge. Kistiakowsky and Bradbury picked the best looking pieces for the Trinity assembly and designated the rest for the full-scale magnetic Creutz test of the gadget to be conducted at Pajarito Canyon without active material. The Trinity charge was assembled on July 12 at V Site in Los Alamos and started on its journey to the Trinity site at midnight, arriving just before noon on the 13th (Bainbridge, 1976). Kistiakowsky wrote that he chose to leave just after midnight on Friday the 13th because he "believed in unorthodox luck" (Kistiakowsky, 1980).

On July 12, two scientists arrived from LANL in an army sedan with the ^{239}Pu core for the implosion device. According to an interview, Phillip Morrison rode down to Trinity with the weapon core. He and Marshall Holloway, both G Division engineers, were designated as the Pit Assembly team in April, 1945, and were responsible for placing the core into the gadget during final assembly. Morrison didn't remember a great deal about the ride to the Trinity site, but did recall that he was "rather afraid of the fast driving young woman who drove us down there with the convoy, who was really a high-speed… pedal to the floor all the way. That driver was the scariest thing" (Morrison, 1999). Brigadier General Thomas F. Farrell signed a receipt for the active material, formally completing the transfer from the scientists to the Army (Jones, 1985). As of 5:45pm on July 13, all components were in place except the detonating system. The device was hoisted to a metal shed on a platform atop a 100-ft steel shot tower, a surplus Forest Service fire-watch tower (Fig. 10-9 and Fig. 10-10) (National Atomic Museum, 2007).

Fig. 10-9. The steel shot tower used for the Trinity test

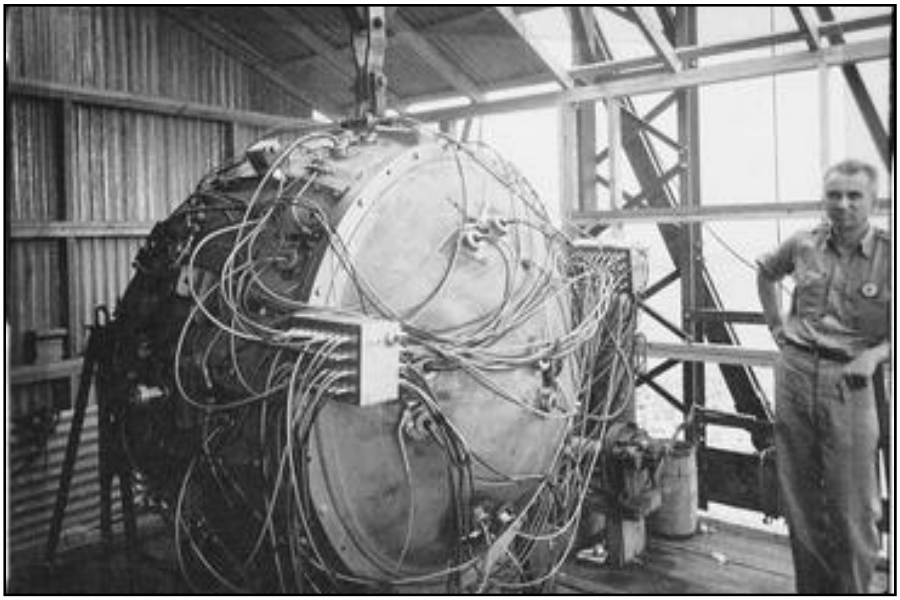


Fig. 10-10. The assembled "Gadget" sits in the metal shed atop the 100-ft metal test tower. To the right in this photo is Norris Bradbury, who would follow Oppenheimer as LANL Director

A truckload of mattresses were piled up under the Gadget in case it fell (Hoddeson et al., 1993). The detonator group completed the firing circuit and technicians added an apparatus for experiments. By 5:00 pm on July 14, the device was ready to test.

Observers, including Office of Scientific Research and Development (OSRD) Director Vannevar Bush and National Defense Research Committee Chairman James Conant, arrived with General Groves on Sunday, July 15. The large contingent from Los Alamos arrived in three buses around 3:00 am on the morning of July 16, just before the scheduled test time of 4:00 am. The weather was rainy, and there were occasional flashes of lightening. General Groves and Oppenheimer decided to delay the shot for an hour and a half. The rain stopped at 4:00 am. Shortly before 5:00 am, with the wind still blowing in the "right" direction, they gave the go-ahead signal for the test (Jones, 1985).

Health and monitoring preparations addressed issues of cloud and trail contamination. According to Hempelmann, resulting activity from the cloud would vary with the efficiency of the explosion, and it would need to be monitored until it was dispersed, since it was a potential hazard to the local population. If loose dust from the crater and the surrounding area rose to 10,000 feet and fell at a normal rate, there might be danger to towns 30 mi away, due to a prediction of 7 R h^{-1} from fission products and the ^{239}Pu tolerance dose being exceeded in 22 h. Hubbard assured all concerned that the meteorological conditions that could affect the cloud were predictable, including low humidity, temperature inversion, winds above the inversion, atmospheric lapse rate, and heating of the earth. Low humidity would exclude a thunderstorm created by the blast and heat effects that could cause precipitation of the active material over a small area. The inversion layer would retard particles from falling until the morning thermals mixed the active material more thoroughly. A 30 mph wind to the SE above the inversion layer would carry the cloud beyond the nearby towns. A stable lapse rate would allow the fire ball to ascend until it reached a higher inversion at 20,000 ft and preclude heavy active particles from falling on a small area. The usual heating of the earth would break the inversion layer and move air in an ascending manner. Hubbard predicted that contaminated material thrown into the air could be suspended for weeks (Bainbridge, 1976).

A betting pool was started by LANL scientists as to what the yield of the Trinity device would be (National Atomic Museum, 2007). Yields from zero to 45,000 tons of TNT (45 kilotons) were selected. Bainbridge was furious when he heard discussions of the possibility that the blast would be hot enough to ignite the nitrogen in the atmosphere and could annihilate the human race (Hacker, 1987). This possible outcome had been suggested by Edward Teller, but fears were quashed by intensive studies by Hans Bethe and others that were documented by Teller and Emil Konopinski in December, 1943. These studies concluded that the safety factor was "at least a factor of 60" (Rosen, 2002).

Bus loads of visitors from Los Alamos and elsewhere started arriving near the Trinity Site around 2:00 a.m. on July 16. Many of those who had no responsibilities during the test situated themselves on Campaña Hill[i] (about 32 km to the northwest of ground zero) to watch the event. These individuals included Ernest O. Lawrence, Hans Bethe, Edward Teller, Robert Serber, Edward McMillan, James Chadwick, and Richard Feynman (Merlan, 2001).

At the time of the detonation, 99 project personnel (about 76 civilian and 23 military) were in the three shelters: 29 at North, 37 at West, and 33 at South. Harvard president James Conant, General Groves, and Vannevar Bush observed the test from a slit trench at Base Camp; J.R. Oppenheimer, Kenneth Bainbridge, George Kistiakowsky, Thomas Farrell, Donald Hornig, and Samuel Allison watched from the South 10,000 shelter, which served as the control point (Maag and Rohrer, 1982, Merlan, 2001). Groves and Oppenheimer purposefully watched the test from different locations, separated by some distance, so that if one were killed, the other could likely continue to manage the project.

The Trinity Test

The Trinity "Gadget" was detonated on Monday, July 16, 1945 at 5:29 a.m. Mountain War Time at latitude 33°28'- 33°50', longitude 106°22'- 106°41', UTM coordinates 630266 on the Alamogordo Bombing Range, New Mexico. The time is not known with exact certainty, since scientists experienced difficulty in picking up station WWV for a time check (Bainbridge, 1976, Maag and Rohrer, 1982).

Observations/Descriptions

The nuclear blast (Fig. 10-11) created a flash of light brighter than a dozen suns (National Atomic Museum, 2007). The light was seen over the entire state of New Mexico and in parts of Arizona, Texas, and Mexico. The resulting mushroom cloud rose to over 38,000 ft within minutes, and the heat of the explosion was 10,000 times hotter than the surface of the sun. At 10 mi away, this heat was described as similar to standing directly in front of a roaring fireplace. Data from hundreds of instruments recorded what occurred that morning. The blast was more powerful than expected, however, and many instruments and experimental devices were ruined (Lamont, 1965). A brilliant yellow light was seen as far away as Albuquerque and Los Alamos to the north, Silver City, New Mexico to the west, and El Paso, Texas to the south. A sensation of heat persisted as a huge ball of fire took shape and transformed into a moving orange and red column. Out of this spectrum rose a narrower column that rapidly spilled over to form a giant white mushroom cloud surrounded by a blue glow. As the glow began to fade, observers at the base camp felt the pressure of the shock wave, and its rumble reverberated for more than five minutes in the

[i] "Campaña" also appears as "Campania," "Campagne," or "Campagna" in various sources. These spellings might have been adopted to help those with little knowledge of the Spanish language pronounce the word.

surrounding hills (Jones, 1985). General Thomas Farrell, Deputy to Gen. Leslie Groves, said that "The effects could well be called unprecedented, magnificent, beautiful, stupendous and terrifying. No man-made phenomenon of such tremendous power had ever occurred before." It was at this moment when Oppenheimer reportedly said, "I am become Death, the Destroyer of Worlds." And Dr. Kenneth Bainbridge, Director of Trinity Test, said "Now we are all sons-of-bitches."

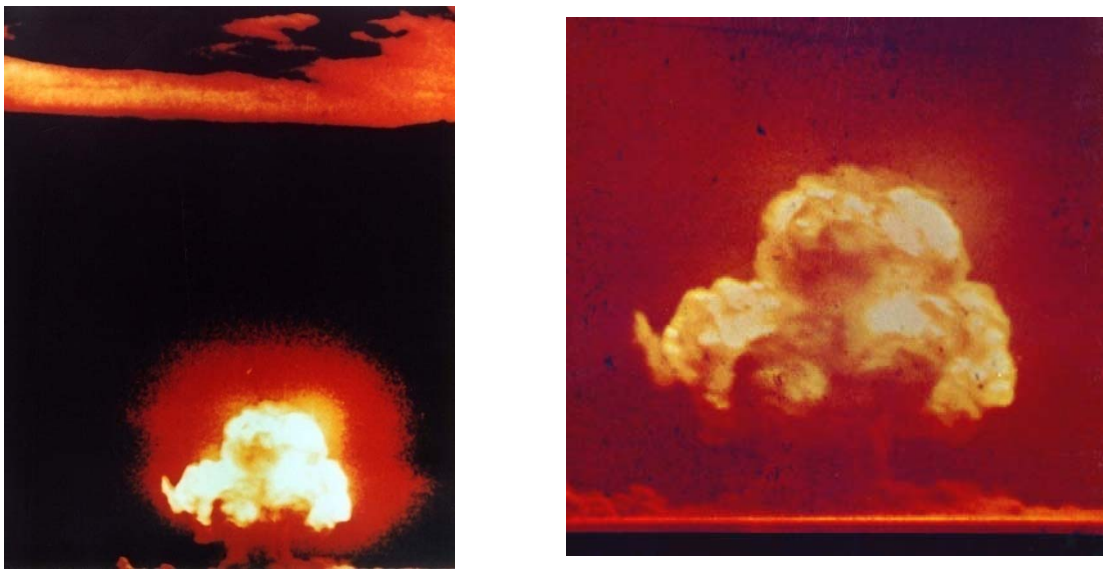


Fig. 10-11. Two images from the only well-exposed color photograph available for the Trinity blast, taken by LANL scientist and amateur photographer Jack Aeby from near Base Camp. As Aeby later said, "It was there so I shot it."

The crew that was at Searchlight Station L-8 observing the cloud from the blast recorded that, at t + 15 minutes, the cloud was divided into three parts—a dense white mushroom cloud, a flat, fairly long red dust cloud, and a reddish-brown column that seemed to come from ground zero (Blair et al., 1945b). The three-man crew was located 19.5 mi from ground zero, to the northeast, as shown in Fig. 10-12. At t + 30 minutes, the high mushroom cloud had moved directly toward their position, and had "taken on the shape of the North American part of the western hemisphere," while the "lower red-brown cloud and column took on the shape of a question mark, while the brown dust seemed to be still emanating from position 0" (Blair et al., 1945b). Radioactive material started to descend upon Searchlight Station L-8 between t + 90 minutes and t + 120 minutes (Blair et al., 1945b). The radiation level peaked at its highest level at 8:25 a.m., and remained constant through 9:15 a.m., after which it started to decline (Blair et al., 1945b).

Physicist Otto Frisch had been taken to a spot about 32 km from ground zero (probably on Compaña Hill). Because he couldn't find his assigned dark glasses as the countdown progressed in the dark that early morning, Frisch initially turned away from ground zero but later recorded the following observations (Frisch, 1979):

"And then, without a sound, the sun was shining; or so it looked. The sand hills on the edge of the desert were shimmering in a very bright light, almost colourless and shapeless. The light did not seem to change for a couple of seconds and then began to dim. I turned round, but that object on the horizon which looked like a small sun was still too bright to look at. I kept blinking and trying to take looks, and after another ten seconds or so it had grown and dimmed into something more like a huge oil fire, with a structure that made it look a bit like a strawberry. It was slowly rising into the sky from the ground, with which it remained connected by the lengthening grey stem of swirling dust; incongruously, I thought of a red-hot elephant standing balanced on its trunk. Then, as the cloud of hot gas cooled and became less red, one could see a blue glow surrounding it, a glow of ionized air; a huge replica of what Harry Daghlian … [saw just over five weeks later at Omega Site in Los Alamos] when his assembly went critical and signaled his death sentence. The object, now clearly what has become so well known as the mushroom cloud, ceased to rise but a second mushroom started to grow from its top; the inner layers of the gas were kept hot by their radioactivity and. Being hotter than the rest, broke through the top and rose to even greater height. It was an awesome spectacle; anybody who has ever seen an atomic explosion will never forget it. And all in complete silence; the bang came minutes later, quite loud though I had plugged my ears, and followed by a long rumble like heavy traffic far away. I can still hear it."

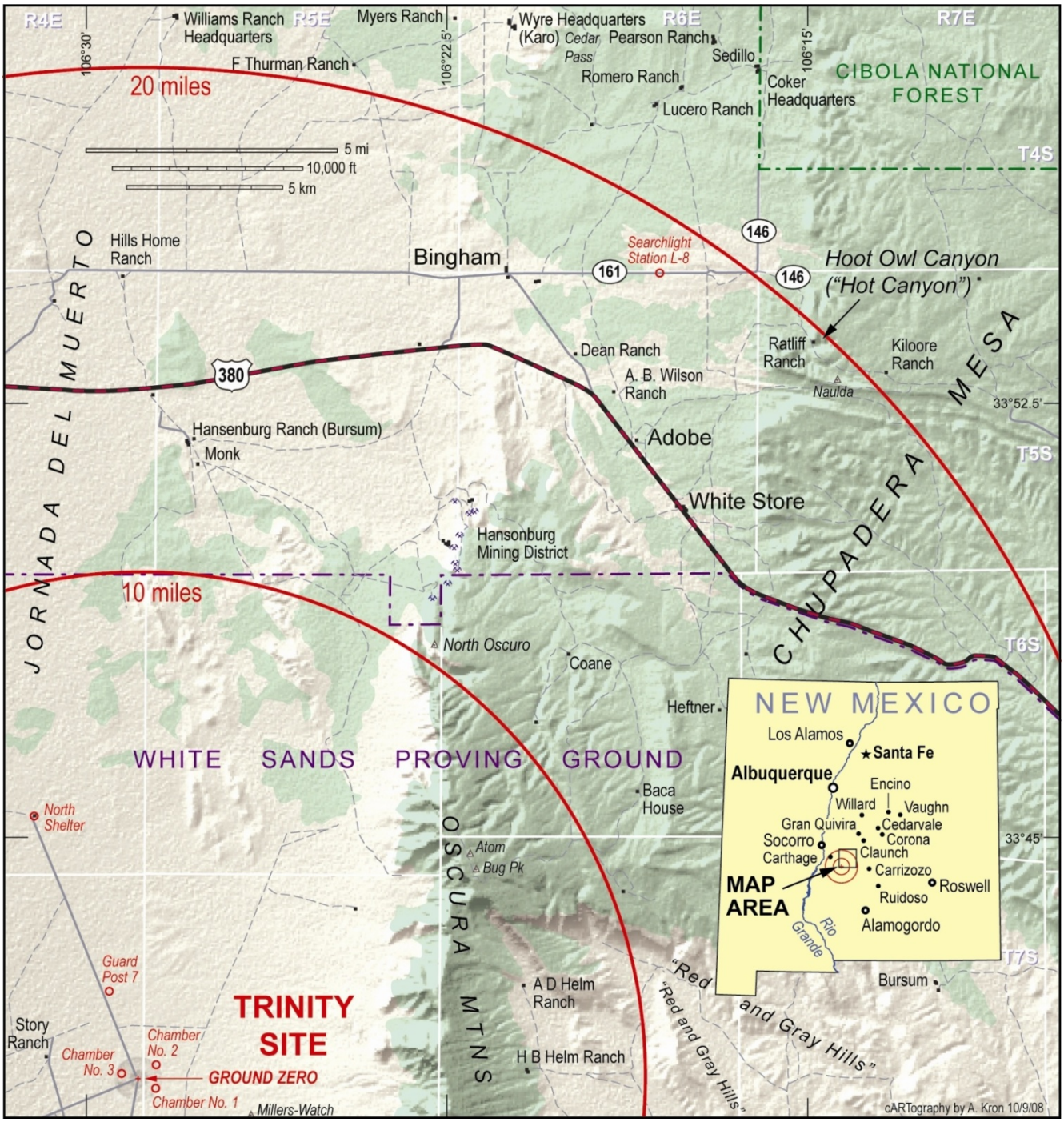


Fig. 10-12. Map of areas to the northeast of the Trinity Site, where highest off-site radiation levels were measured after the July 1945 shot.

Less than a half hour after the test shot, General Groves called his secretary in Washington, D.C. to pass on word of the test to Secretary Stimson. Groves reported that the strength of the explosion was at least "satisfactory plus and perhaps far greater than estimated" (Lamont, 1965).

Cloud Trajectory and Fallout Observations

Up to the time of the shot, and for the first half hour information about the cloud's direction of travel was vague. A 20 mi h^{-1} wind was blowing from the southeast toward Guard Gate 2[i] to the northeast of ground zero. It was thought that the radioactive cloud would move in a line toward the northwest from ground zero, but the cloud did not end up traveling in that direction (Hoffman, 1947). Col. Stafford Warren, Chief of the Manhattan Project's Medical Section, documented the following in a July 21, 1945 report to Gen. Groves (Warren, 1945):

> "The energy developed in the test was several times greater than that expected by scientific group. The cloud column mass and top reached a phenomenal height, variously estimated as 50,000 to 70,000 feet. It remained towering over the northeast corner of the site for several hours. This was sufficient time for the majority of the largest particles to fall out. Various levels were seen to move in different directions. In general, the lower one-third drifted eastward, the middle portion to the West and northwest, while the upper third moved northeast. Many small sheets of dust moved independently at all levels and large sheets remained practically in situ. By zero plus 2 hours, the main masses were no longer identifiable except for the very high white mass presumably in the stratosphere.
>
> By 0800 hours the monitors reported an area of high intensity in a canyon 20 mi northeast of zero. … Intensities in the deserted canyon were high enough to cause serious physiological effects.
>
> The distribution over the countryside was spotty and subject to local winds and contour. It skipped the nearby highway #380 (20 mi. N.E.) except for low intensities which were equaled at twice and three times the distance. It is presumed that the largest outfall occurred in the N.E. quadrant of the site. This can only be explored by horseback at a later date."

Between 6:00 and 7:00 am, the wind direction changed from southeasterly to southwesterly[ii], and the cloud was traveling northeast at 15 mi h^{-1}, at altitude 35,000 ft, and rising about 14,000 ft h^{-1}. Monitors found readable gamma radiation 1.7 h after the shot 19 mi from ground zero, indicating that the active

[i] Guard Gates or Guard Posts were typically just tents or parked trucks along the roadside used to provide shelter for security guards who controlled access to the various areas of the Trinity Site.

[ii] Although typical in many historical reports, this summary follows the convention of describing wind directions as the directions directions that the wind is blowing *from*.

dust falling from high altitudes had been caught by the northwesterly wind near the ground and blown in the direction of Socorro (Hoffman, 1947).

The cloud drifted northeastward at about 10 mi h^{-1}, dropping its trail of fission products across a region measuring 100 mi long and 30 mi wide (Lamont, 1965). In the deep ravines northeast of the Trinity site, where cattle grazed, the radioactivity settled in a white mist (Lamont, 1965). The off-site monitors feared inversions and solar heating of air in the canyons, which could cause thermal updrafts that could lead to sudden wind shifts and carry airborne contamination beyond the expected limits, possibly dumping it in some remote area unknown to the monitors (Lamont, 1965).

William Wrye, whose house was 20 mi northeast of Trinity, reported that "for four or five days after that, a white substance like flour settled on everything" (Albuquerque Journal News, 1995). And rancher M. C. Ratliff said that "the ground immediately after the shot appeared covered with light snow," adding that for several days afterward, especially at dawn and dusk, "the ground and fence posts had the appearance . . . of being frosted" (Hacker, 1987).

As the cloud drifted beyond Carrizozo, with monitoring teams in full chase, scientists realized that the monitors had overreached the limits of their radio contact with base camp. As fallout was dropping on northern communities like Coyote, Ancho, and Tecolote, the monitors were unable to relay the results to Stafford Warren at Base Camp (Lamont, 1965). Even as officials at base camp were advising Washington that the fallout danger was diminishing, the monitors were racing back toward Trinity with reports that fallout had reached a number of areas beyond their jurisdiction, such as Vaughn (Lamont, 1965).

The [visible] cloud from the Trinity blast appears to have dissipated over the vicinity of Vaughn, 96 mi from ground zero. It appears that the main cloud wrapped itself around Gallinas Peak, 65 mi north of the site, and broke up (Lamont, 1965). There is evidence that fallout from the Trinity test traveled as far as Indiana. In the fall of 1945, the Kodak Company observed some spotting on their film, and they traced it back to contamination in their cardboard. Dr. J.H. Webb, a Kodak employee, studied the matter and concluded that the ^{141}Ce contamination must have come from a nuclear explosion somewhere in the U.S. In fact, it had come from the Trinity Test (Webb, 1949).[i] Fallout from the explosion had contaminated the river water that the paper mill in Indiana had used to manufacture the cardboard pulp. Recognizing the sensitivity of this information, Dr. Webb kept his discovery secret until 1949 (Webb, 1949).

[i] Memorandum by Julius H. Webb, "Fogging of film by radioactive contaminants at Eastman Kodak Company," March 15, 1949. 1949. In: LANL Archives Collection A-1999-019, Box 69, Folder 14.

Airplanes equipped with filters followed the Trinity cloud across Kansas, Iowa, Indiana, upstate New York, New England, and out to sea (Blair et al., 1945a).

Witnesses from Outside the Project

Because of the intense secrecy surrounding the test, accurate information of what actually happened was not released to the public until after the second atomic bomb had been dropped on Japan three weeks later. Without being officially informed, many people in New Mexico were well aware that something extraordinary had happened the morning of July 16, 1945. The blinding flash of light, followed by the shock wave, had made a distinct impression on people who lived within a radius of 160 mi of ground zero. Windows were shattered 120 mi away in Silver City, and residents of Albuquerque saw the bright light of the explosion on the southern horizon and felt the tremor of the shock waves moments later (National Atomic Museum, 2007).

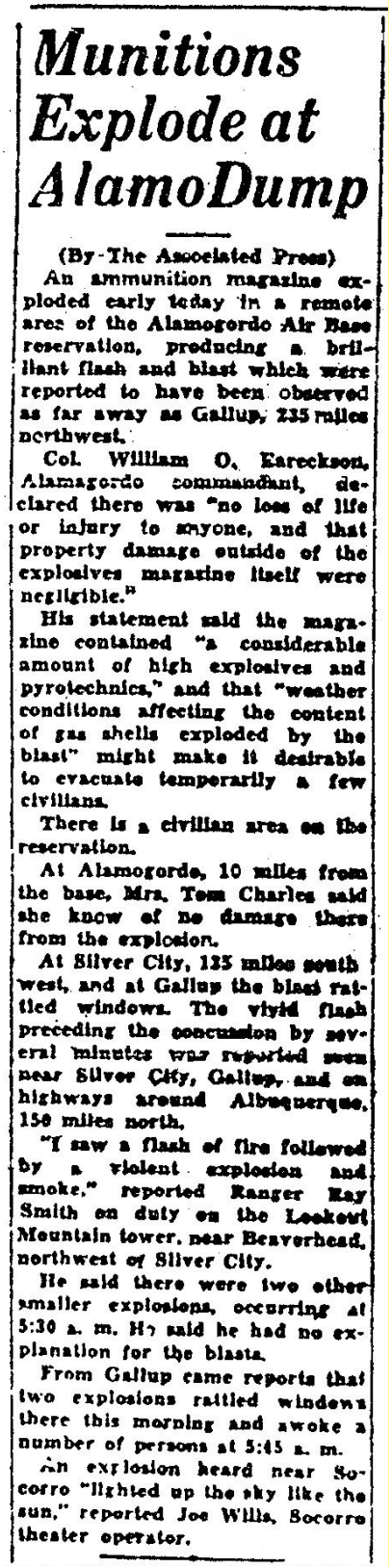
In spite of the "no fly" order, pilot John Ellison, a flight engineer, and four trainees took off from Roswell Air Field in a B-29 just before 5 a.m. on July 16, 1945. They were on a training mission for the 9- to 12-h bombing missions planned over Japan, and had been cleared to fly to California. About 42 min into the flight, they were 18,000 ft over the northern part of the Sacramento Mountains bordering the White Sands Missile Range when they saw a searing light and the red fireball of the first atomic bomb test. Ellison estimated that he and his crew were 15-20 mi from ground zero, and may have been the closest individuals to witness the test from the air. This estimation is likely to be true, as the two B-29 observation planes were unable to take off from Kirtland Field because of bad weather, including heavy clouds and thunder storms (Groves, 1945). Ellison radioed the tower in Roswell, and its staff told him to get the plane back. Later he learned that authorities associated with the atomic test overheard his radio transmission and ordered the base to call in the planes (Santa Fe New Mexican, 2005).

The "Cover Story"

An officer from General Grove's headquarters provided a cover story to the commander of the Alamogordo Air Base to be issued as soon as the test had occurred. Another officer was stationed in the Associated Press office in Albuquerque to suppress any stories that might alarm the public. Groves also arranged with the Office of Censorship in Washington, D.C. to keep news of the explosion from getting into newspapers in other parts of the country. The Army issued an order grounding all commercial planes and suspending all flights from nearby military installations (Jones, 1985). Groves modified the cover story to fit the exact circumstances of the test, and gave permission to the Associated Press at Albuquerque to release it as follows:

"Alamogordo, N.M., July 16. The commanding officer of the Alamogordo Air Base made the following statement today: Several inquiries have been received concerning a heavy explosion which occurred on the Alamogordo Air Base reservation this morning. A remotely located ammunition magazine containing a considerable amount of high explosives and pyrotechnics exploded. There was no loss of life or injury to anyone, and the property damage outside of the explosive magazine itself was negligible. Weather conditions affecting the content of the gas shells exploded by the blast may make it desirable for the Army to temporarily evacuate a few civilians from their homes" (Jones, 1985).

Fig. 10-13 shows an article that resulted from release of this cover story.



Munitions Explode at AlamoDump

(By The Associated Press)

An ammunition magazine exploded early today in a remote area of the Alamogordo Air Base reservation, producing a brilliant flash and blast which were reported to have been observed as far away as Gallup, 235 miles northwest.

Col. William O. Eareckson, Alamogordo commandant, declared there was "no loss of life or injury to anyone, and that property damage outside of the explosives magazine itself were negligible."

His statement said the magazine contained "a considerable amount of high explosives and pyrotechnics," and that "weather conditions affecting the content of gas shells exploded by the blast" might make it desirable to evacuate temporarily a few civilians.

There is a civilian area on the reservation.

At Alamogordo, 10 miles from the base, Mrs. Tom Charles said she know of no damage there from the explosion.

At Silver City, 135 miles south west, and at Gallup the blast rattled windows. The vivid flash preceding the concussion by several minutes was reported seen near Silver City, Gallup, and on highways around Albuquerque, 150 miles north.

"I saw a flash of fire followed by a violent explosion and smoke," reported Ranger Ray Smith on duty on the Lookout Mountain tower, near Beaverhead, northwest of Silver City.

He said there were two other smaller explosions, occurring at 5:30 a. m. He said he had no explanation for the blasts.

From Gallup came reports that two explosions rattled windows there this morning and awoke a number of persons at 5:45 a. m.

An explosion heard near Socorro "lighted up the sky like the sun," reported Joe Wills, Socorro theater operator.

Fig. 10-13. An Associated Press article that resulted from the Trinity cover story

Experimental Results

Immediately after the test, Sherman M-4 tanks, painted white, equipped with their own air supplies, and lined with two inches of lead went out to explore the crater area. The lead added 12 tons to each tank's weight, but was considered necessary in order to protect the tank occupants from the radiation levels at ground zero. The tank passengers found that the 100-foot steel tower had virtually disappeared; only the metal stumps of its legs remained imbedded in concrete (USDOE, 1994).

The most important result of the test, though, was that the implosion device actually worked. The yield was three times larger than predicted; T-Division's predictions were between five and ten kilotons. Radiochemical analysis of the soil samples gave an estimated yield of 18,600 tons of TNT, quite close to the currently accepted value of 20 to 22 kilotons. Some of the observers tried to estimate the yield while watching the test. Enrico Fermi performed a fairly simple experiment, in which he tore a sheet of paper into pieces and dropped them as the blast wave passed his location.

They moved about 2.5 ft, which Fermi calculated to be equivalent to 10,000 tons of TNT.

The Socorro Chieftain carried the following item after the Trinity Test, but before the true story of what had happened was released:

> "An explosives magazine at the Alamogordo air base blew up Monday morning [*see 'The Cover Story,' below*], and the flash, sound and shock were seen, heard and felt in Socorro, more than 100 mi away . . . The flash was intensely white and seemed to fill the entire world. It was followed by a large crimson glow. The flash lasted only a second or so. It was so bright that Miss Georgia Green of Socorro, a blind student at the University of New Mexico, being driven to Albuquerque by her brother-in-law, Lieutenant Joe Wills, asked, "What's that?"

The blast measuring devices performed well, but the gamma ray measuring devices were overloaded. The higher gamma radiation fogged the motion picture films slightly, and ruined the measurements of detonator simultaneity. Few neutron detectors survived the blast. Seven of the gold foils were recovered. No gauges with 200 ft of ground zero survived. The seismographs detected a tremor at the North shelter, and at San Antonio 28 mi away. The yield and size of the fire ball prompted scientists to specify the height of the Hiroshima and Nagasaki bombs as 1,850 ft (Hoddeson et al., 1993). According to Bainbridge, 1% of the fission products were left in the crater and its vicinity (Bainbridge, 1976). Because of the presence of dust around ground zero, "a large region of the countryside was contaminated by fission products." This contamination is discussed in more detail in a LANL report (Hirschfelder et al., 1945).

Because of the storm conditions on the morning of the 16th, Oppenheimer asked Waldman and Alvarez not to fly over ground zero to drop the gauges that would radio data back to the B-29s since the flight would be too dangerous (Hoddeson et al., 1993).

Local Conditions

Fig. 10-14 shows an aerial photograph of the area around ground zero at 28 h after the test. The blackened area shows the radius of intense heat that burned off all the vegetation. The blast effect in this area and the resulting updraft of hot gases removed a thin layer of soil and burned debris from the blast area.

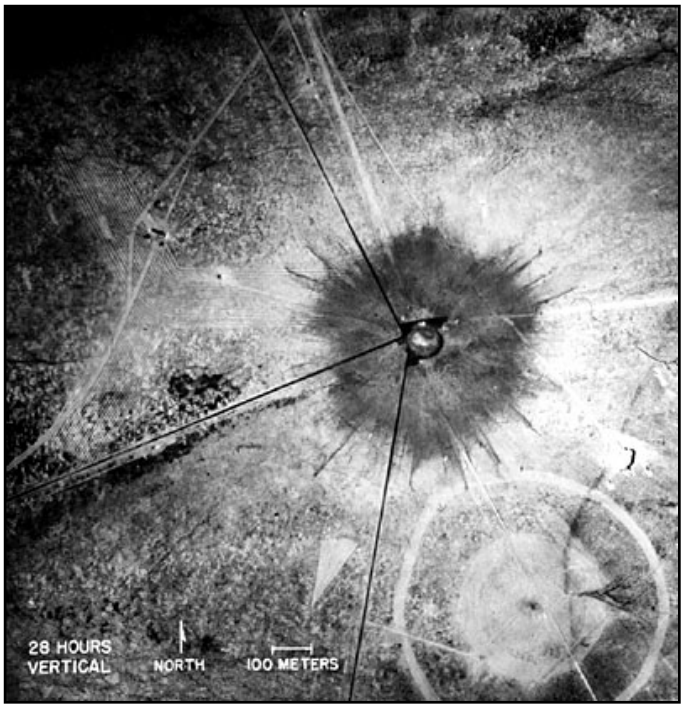


Fig. 10-14. Aerial view of the Trinity ground zero (center) at 28 h after the shot. The circle to the lower right is from the 100-Ton Test, with its detonation point exactly 1 mi distant.

Off-site Consequences Measurement and Management

While not much was said publicly about measurements of off-site fallout from the Trinity test for years after the shot, advance planning and preparation did take place before the test to establish the ability to measure off-site radioactivity and promote public safety to the extent allowed during war time, in the face of many other competing objectives.

Competing Priorities for Secrecy, Security, Safety, and Litigation Avoidance

Writing 25 years after the Trinity test, General Groves described what had been the six immediate military requirements for adequate Project Trinity security (Hacker, 1987). While the General's recollections might have reflected 1970 as well as 1945 views, the list of requirements for security is informative:

- Barring strangers from the test site;
- Preventing harm to project members;
- Reducing chances that outsiders could learn of the explosion;
- Safeguarding the public from fallout;

- Planning for emergency evacuation; and
- Forestalling any national press reports that might alert Japan.

Testing an atomic bomb on American soil, no matter how remote the site, clearly threatened the secret of the atomic bomb project— the most violent man-made explosion in history could hardly pass unseen. It was important that the Japanese not be alerted, and elaborate public safety precautions seemed likely to only make the event more noticeable (Hacker, 1987). But, fortunately, to some degree, the same measures that kept Trinity safe from prying eyes also helped keep the public safe from the test, and testers safe from lawsuits (Hacker, 1987).

When General Groves visited LANL in April, 1945 for a briefing on the Trinity plans, his first questions were about legal matters (Hacker, 1987). He was concerned about damage or harm from earth shock, air blast, and toxic effects, and felt that valid records would help secure the army against damage claims. This concern explains why, for example, 20 government agents were stationed in towns up to 100 mi from ground zero on shot day, equipped with recording barographs, seismographs, and recording radiation m to measure remote shock, blast, and radiation (Hoffman, 1947, Bainbridge, 1976, Hacker, 1987).

Until just weeks before the test, fallout simply appeared to be a minor problem. LANL's "plans to send out radio equipped cars provided with instruments for measuring alpha particle and gamma ray intensities in outlying areas" met with Groves's approval (Hacker, 1987). It was added that "on the basis of these measurements, evacuation of inhabitants could be carried out if necessary." Groves dismissed any thoughts of giving advance warning to nearby ranchers and townsfolk, because "the danger seemed modest given the proper weather" (Hacker, 1987). Keeping the secret, though, forced some safety compromises (Stannard, 1988).

Shortly before the field test, updated calculations provided indication that fallout could be more substantial and widespread than originally thought (Hacker, 1987, Stannard, 1988). While there was considerable discussion regarding whether assumptions on which those calculations were based were overly pessimistic, the fallout calculations completed shortly before June 23, 1945 provided predictions that were sobering, and establishing monitoring and evacuation plans seemed more prudent (Hacker, 1987). Figure 10-15 shows the locations of ranches, farms, towns, and camps within approximately 40 mi of Trinity ground zero that are labeled on USGS 1:250,000 maps issued in 1954.

General Groves and the Manhattan Project's Medical Director, Stafford Warren, are said to have known that the Army was not eager to pursue too diligently the possibilities of widespread fallout (Lamont,

1965). The specter of endless lawsuits haunted the military, and most of the authorities simply wanted to put the whole test and its after-effects out of sight and mind (Lamont, 1965).

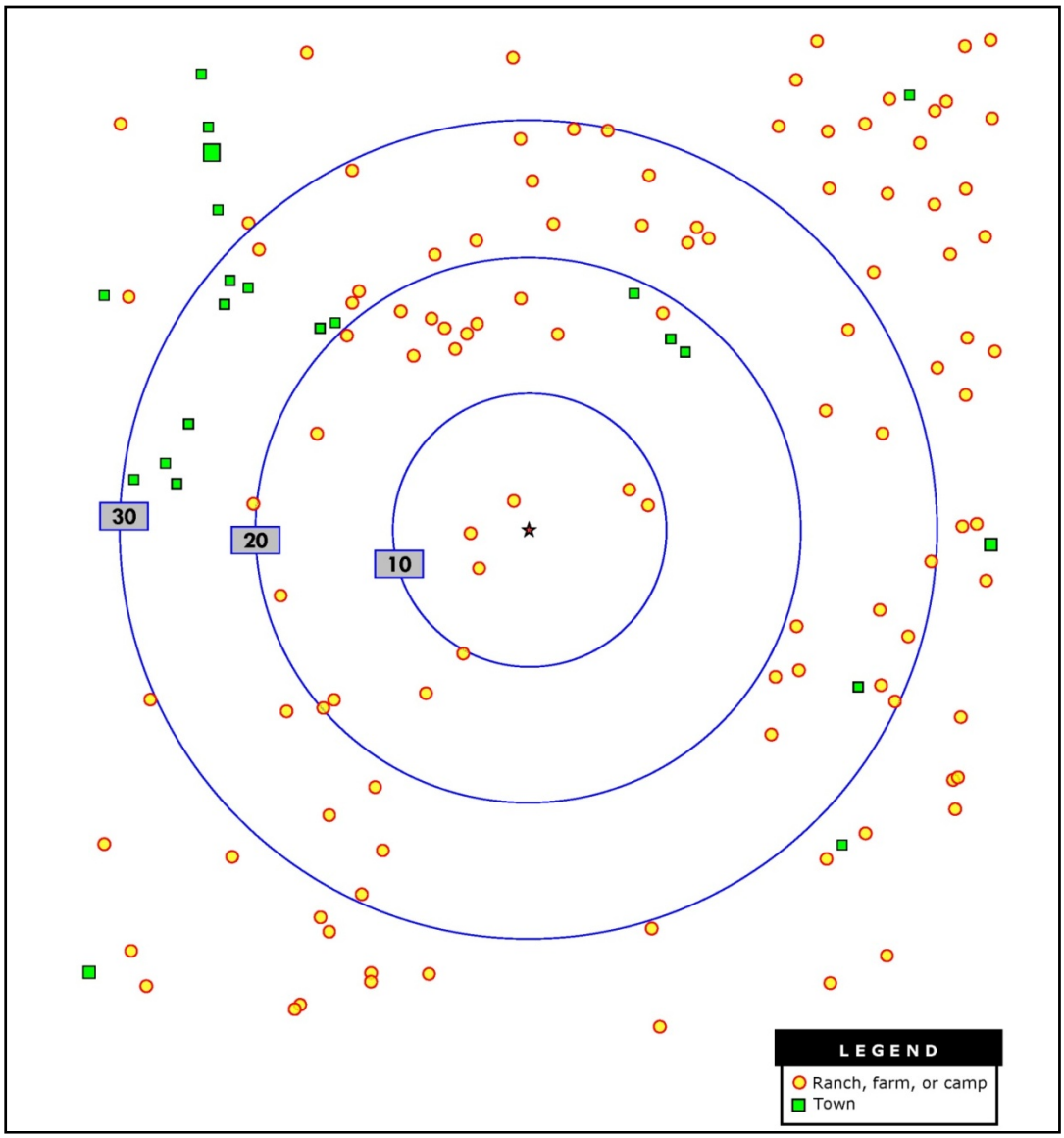


Fig. 10-15. Locations of ranches, farms, camps, and towns within about 40 mi of Trinity Site ground zero based on USGS 1:250,000 maps issued in 1954. Circles are at radii of 10, 20, and 30 mi.

Potential Public Exposure Pathways

Members of the public could have been exposed to radiation and radioactive materials from the Trinity event by a number of pathways, including:

1. Direct, prompt radiation from the blast itself;
2. Direct, external irradiation from the cloud passing overhead or nearby;
3. Direct, external irradiation from being immersed in the cloud;
4. Direct, external irradiation from contamination deposited on the ground;
5. Direct, external irradiation from contamination deposited on the skin, hair, or clothing;
6. Internal dose from inhalation of airborne contamination;
7. Internal dose from inhalation of re-suspended fallout particles;
8. Internal dose from ingestion of contaminated food products.

Initial radiation from fission and other processes in the explosion ceased in less than a minute, as delayed neutrons lasted only seconds; radiation from the fire ball, although substantial, decreased as the square of distance and was further attenuated by air. Ten thousand feet from ground zero, well within site boundaries, radiation was too low to detect (Hacker, 1987).

Pathway one was apparently relatively insignificant to members of the public. Had it been significant, it would have shown up on the "remote sentinel robot ionization chambers" that spotted the main access roads at distances between 400 and 10,000 yd (Hoffman, 1947, Hacker, 1987) and the recording gamma m that were stationed in local towns.

The post-shot radiological monitoring program conducted by LANL scientists with the assistance of military personnel addressed, to the extent possible with the equipment available at the time, pathways two, three, and four dealing with direct exposure from radioactivity in the cloud or deposited on the ground. This assessment was accomplished by having field monitoring crews collect data, which were then analyzed and reported in documents assembled by Hoffman and others.

The post-shot radiological monitoring program, however, did not focus on assessing pathways five through eight. No monitoring of contamination on the bodies of members of the public was performed (such as frisking or collecting wipe or wash samples). This pathway was found to be important for livestock, though, since they stay mostly outdoors, do not wear clothes, and do not bathe. It was reported that cattle that grazed on Chupadera mesa suffered local beta burns and temporary dorsal hair loss (Hempelmann, 1947, Hacker, 1987, Stannard, 1988). Patches of hair grew back discolored. The Army bought 75 head in all from ranchers; the 17 most significantly marked were kept at LANL, while the rest

were shipped to Oak Ridge for long term observation. Doses required to produce such effects were estimated to be between 4,000 and 50,000 r, and most likely around 20,000 r (Hacker, 1987).

While there is documentation that samples of airborne particles were taken using ten Filter Queen air samplers (modified vacuum cleaners), and that soil samples were reportedly taken using large-mouthed jars provided to monitoring crew members (Hoffman, 1947), we have located no analyses of subsequent radiometric or radiochemical analyses of these samples, nor have we located risk assessments that address exposures to Trinity workers or to members of the public from internally deposited radioactivity following inhalation or ingestion of radioactivity from the Trinity blast.

Dose Limits and Action Levels for Public Evacuation

The recovery of data from the Trinity test took precedence over general safety standards (Hacker, 1987). The 0.1 R d^{-1} standard for workers in day-to-day operations at LANL was replaced for Trinity by a statement that "no person should (of his own will) receive more than five (5) r at one exposure" (Hacker, 1987). When pressed to decide how high of a radiation exposure to consider safe for those with no part in, or knowledge of, the Trinity test (that is, members of the public), Hempelmann and Nolan assured Bainbridge that a total dose of 68 R spread over two weeks "would certainly not result in permanent injury to a person with no previous exposure . . . It would probably not even cause radiation sickness. A normal person could probably stand two to three times this amount without sustaining permanent bodily damage. Fatalities would not result unless ten or more times this dose were delivered" (Hacker, 1987; Stannard, 1988). Concern focused on immediate hazards, sincewithin the health physics community "the thinking had not yet focused on possible long-term effects" (Stannard, 1988). It was clear that evacuation would require an "extreme emergency" (Hacker, 1987). Stafford Warren stated that he would begin to worry only if peak exposure rates reached 10 R h^{-1} , and said that the best approach would be to take "measurements for several hours and consider evacuation if total dose reached final total of 60-100 r" (Hacker, 1987).

Two days before the test, Warren and Hempelmann agreed to "set the upper limit of integrated gamma ray dose for the entire body over a period of two weeks (336 hours) as 75 roentgens," and also agreed on an "upper safe limit of radiation … [of] 15 r/hr at peak of curve" (Hacker, 1987).

Off-Site Monitoring Team Staffing and Positioning

Four two-man, off-site monitoring teams and one five-man team supervised by the chief off-site monitor constituted the off-site monitoring crew led by Joseph Hoffman (Fig. 10-16).

The teams were manned as follows, with initial placement as indicated (Hoffman, 1947, Maag and Rohrer, 1982):

- Alfred Anderson with Julian Bernacci at Nogal, NM (about 55 mi ESE)
- Joel Greene with Charles Nally at Roswell, NM (about 110 mi ESE)
- Carl Hornberger with Richard Foley at Fort Sumner (about 140 mi NE)
- Robert Leonard with William McElwreath at Socorro, NM (about 30 mi NW)
- Wright Langham, Phillip Levine, John Magee, Joseph Hirschfelder, and Joseph Hoffman (the chief monitor) were at Guard Gate 2.

The five-man team remained at Guard Gate 2 to assist with evacuating nearby residents if the cloud from the shot drifted toward the northwest. These residents, specifically those in the Fite Ranch house and the homes in the town of Tokay, were roughly 15 and 20 mi northwest of ground zero, respectively (Maag and Rohrer, 1982). From Guard Gate 2, those monitors could also be dispatched toward Carthage, Bingham, Claunch (about 50 mi NE), and Carrizozo.

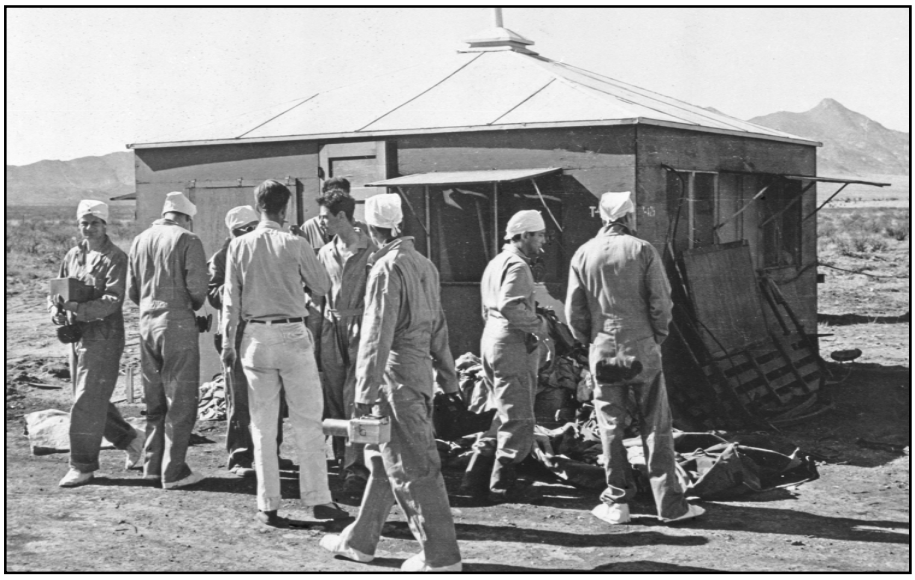


Fig. 10-16. Recovery team and radiation monitoring crew members after the Trinity blast

Equipment Used for Off-Site Monitoring

Each off-site monitoring team was provided with the following equipment (Hoffman, 1947):

- A methane filled proportional counter for detecting alpha particle radiation in the presence of beta and gamma radiation;

- A Victoreen Model 247 portable gamma ray survey m with three ranges;
- A Hallicrafter Model 5 portable Geiger-Mueller survey m for gamma radiation and mixtures of gamma and beta;
- Large-mouthed bottles for collecting soil samples; and
- A map showing names and locations of residents within a radius of 40 mi of ground zero.

Landsverk and Wollan quartz-fiber electrometers ("L & W meters") were also used, at least at Searchlight Station L-8, as were "meters obtained from R. Watts, " also known as Watts-type m (Blair et al., 1945b, Hacker, 1987). All off-site monitoring teams were supposed to be in radio or telephone contact with personnel at Base Camp, but communications were problematic, and information could not always be shared (Hoffman, 1947, Lamont, 1965, Maag and Rohrer, 1982).

In addition to the instruments carried in automobiles, the following stationary equipment was used (Hoffman, 1947):

- The three shelters (North, South, and West) were equipped with an alpha m, a beta-gamma GM m, and a survey m;
- At the Base Camp, a Filter Queen airborne particulate sampler, and a GM recording m were used;
- At the towns of Tularosa, Hot Springs, San Antonio, and Carrizozo, a Filter Queen, a recording beta-gamma m, and a seismograph were set up.

Travel of Off-Site Monitoring Teams

Based on observed surface winds, scientists thought that contamination was blowing in a line toward the northwest from ground zero during the first half hour after the shot. As a result, an early attempt was made to monitor around Fite's Farm just past Guard Gate 2 (see Fig. 10-3). A Military Police officer refused to allow the monitoring team to enter that area, however, until permission was received from Base Camp. That permission came only after the cloud had passed, however, so attention was diverted elsewhere. Around 7:11 am, a monitoring team found detectable gamma radiation 19 mi from ground zero in the direction of Socorro (toward the northwest) (Hoffman, 1947).

After the cloud's path appeared to shift toward the northeast, monitors focused on areas along, or near, Route 380 past Carthage and between Bingham and Carrizozo (see Fig. 10-12). Monitoring teams visited Adobe and White Store to the east along Route 380, and some traveled all the way to Carrizozo. Teams traveled north from Bingham on Road 146 to monitor ranches in that area, such as the Coker, Lucero, and Sedillo ranches. Just east of Bingham, the highest levels of elevated radioactivity were found around

Searchlight Station L-8 and in the rugged areas to its southeast. About two mi east of the 146/161 junction, Road 146 runs through a steep gorge. The highest exposure rates were found there, leading it to be called "Hot Canyon" (see Fig 10-12 and 10-17). Hoffman wrote "since the canyon was hot, extensive measurements could not be made there on account of instrument contamination" (Hoffman, 1947).

Puzzled by the high readings reported from Hot Canyon, Drs. Hempelmann and Friedell went to the area on July 17, the day after the shot, and discovered an adobe house hidden from the road, about a mi east of where the highest readings had been taken (Hacker, 1987). An elderly couple lived there with a young grandson, several dogs, and assorted livestock (Hoffman, 1947, Hacker, 1987). The Ratliff ranch had been overlooked by the Army, and it was not on the copies of "Palmer's map of inhabited localities" that monitoring crews were given. A second ranch, unknown to the army, was discovered later. As it turned out, a couple with the last name of Wilson lived near the Ratliffs, and early reports confused the two residences (Hemplemann, 1947, Hoffman, 1947, Hacker, 1987).

Although there was no record of what the exposure rates were at the Ratliff ranch on shot day, the doctors decided that the exposure rates at the ranch on the 17th were not high enough to warrant "hasty evacuation" (Hacker, 1987). As mentioned earlier, rancher M.C. Ratliff said that "the ground immediately after the shot appeared covered with light snow," adding that for several days afterward, especially at dawn and dusk, "the ground and fence posts had the appearance . . . of being frosted" (Hemplemann, 1947, Hacker, 1987).

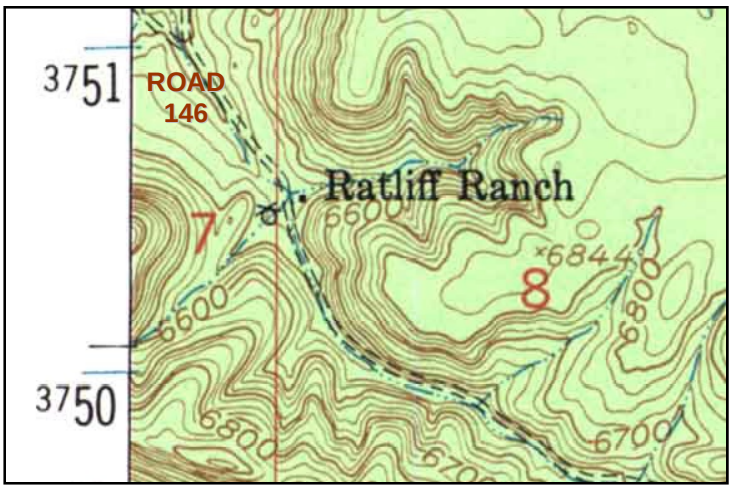


Fig. 10-17. USGS Topographic map excerpt showing the area around the Ratliff Ranch
(Broken Back Crater, N. Mex., 15-min.series, 1948. Contour interval = 25 ft)

Results of Off-Site Monitoring

Results of the off-site monitoring conducted by 44 individuals after the Trinity test are documented in handwritten notes, typed transcripts of these notes, and in summary forms (NTA, 1946, Hempelmann, 1947, Hoffman, 1947, Lamont, 1965, Maag and Rohrer, 1982, Quinn, 1987). Table 10-1 contains a summary of field team monitoring results recorded on July 16-17, 1945 that reached intensities of 100 mr h^{-1} or higher. After the trajectory of the cloud shifted toward the northeast, monitors focused mostly on areas along, or near, U. S. Route 380 to the east of Carthage and between Bingham and Carrizozo. Measured exposure rates first reached 100 mr h^{-1} at Searchlight Station L-8 around 7:30 a.m. Measurements in Bingham (30 km northeast of ground zero) reached 1.5 r h^{-1} by 8:25 a.m. and peaked at 3.3 r h^{-1} at 8:49 a.m. Gamma radiation levels in Adobe (5.4 km southeast of Bingham) were 6.5 r h^{-1} at 8:49 a.m. and fell to 1.6 r h^{-1} by 10:18 a.m. About 3 km farther southeast, in White Store, the highest recorded result was 3 r h^{-1} at 10:30 a.m.

The highest gamma intensities were found in the "Hot Canyon" area. Monitoring in the area of the canyon found gamma intensities up to "the vicinity of 20 R/hr" at 8:30 a.m. that dropped off to 6.0 R h^{-1} by 1:30 p.m. and 3.8 R h^{-1} by 1:57 p.m. (Hoffman, 1946, NTA, 1946, Hoffman, 1947). Teams traveled north from the Bingham/L-8 area on Route 146 to monitor the Coker, Lucero, and Sedillo ranches. Gamma radiation above background was measured in the school yard at Vaughn [96 mi to the northeast of ground zero] 7.6 h after the blast, indicating that the cloud traveled no slower than 12.9 mi h^{-1} (Hoffman, 1947). On the day after the blast, exposure rates as high as 300 mr h^{-1} were measured near

Corona and Claunch, while exposure rates from three to 11 mi north of Vaughn ranged between 0.1 R h^{-1} and ">> 0.1" r h^{-1} shortly after 3:00 p.m.. At no location greater than ten mi distant from ground zero was an alpha particle count obtained that could easily be distinguished from background with the instruments the monitors were using (Hoffman, 1947).

At about 3:30 p.m. on the day of the blast, the recording G-M counter at Carrizozo began to track upward. About 15 min later, that m went off scale on its least sensitive scale, and the monitor notified Base Camp by telephone (Hoffman, 1946, Lamont, 1965). Full scale on that recorder corresponded to 10,000 counts per minute ("cpm") (Hoffman, 1947). After one hour, the gamma intensity at Carrizozo was measurable on a single-scale Victoreen survey m that indicated an intensity of 1.5 mr h^{-1} until the following morning (Hoffman, 1946, NTA, 1946). By 10:00 a.m., the G-M counter reading had decreased to 3,000 cpm.

Table 10-1. Exposure rates 0.1 R h^{-1} or greater measured July 16-17, 1945 near Trinity Site

Date and Time	Off-Site Location[a]	Recorded Exposure Rate (r h^{-1})
7:30 a.m.	Searchlight Station L-8	0.1
7:45 a.m.	11-16 km W of Carthage on US 380	0.2
8:00 a.m.	Searchlight Station L-8	0.5
8:25 a.m.	Bingham	1.5
8:25 to 9:15 a.m.	Searchlight Station L-8	2.0
8:29 a.m.	0.4 km W of Hansenburg Ranch	0.25
8:30 a.m.	Searchlight Station L-8	0.1
8:30 a.m.	5.6 km SE of L-8 ("Hot Canyon" area)	"vicinity of 20"
8:35 a.m.	Searchlight Station L-8	2
8:42 a.m.	1.6 km E of Bingham along US 380	1.0
8:45 a.m.	3.3 km W of Bingham	1.6
8:45 a.m.[c]	"Cooler spot" retreated to from 8:30 spot in canyon	15
8:46 a.m.	3.2 km E of Bingham along US 380	2.2
8:47 to 8:56 a.m.	From Searchlight Station L-8 to Hot Canyon	1.2 to 14.5
8:49 a.m.	Bingham	3.3
8:49 a.m.	6.4 km E of Bingham along US 380 (Adobe)	6.5
8:50 a.m.	4.8 km E of Searchlight Station L-8	15.0
8:50 a.m.	Hansenburg Ranch	0.45
8:56 to 9:40 a.m.	From Hot Canyon to Searchlight Station L-8	1.5 to 6.5
9:05 a.m.	4.8 E of Searchlight Station L-8	15.0
9:30 a.m.	Searchlight Station L-8	1.0
9:40 to 10:15 a.m.	N from L-8 to Rte. 41 cutoff to Maxwell Ranch	1.1 to 6.0
10:00 a.m.	0.8 km S of Hansenburg Ranch	0.8
10:15 to 10:50 a.m.	From Rte. 41 near Maxwell Ranch back to L-8	1.5 to 4.8
10:18 a.m.	6.4 km E of Bingham (Adobe)	1.6
10:22 a.m.	6.4 km E of Bingham along US 380	1.5
10:25 a.m.	9.7 km E of Bingham along US 380	3.0
10:25 a.m.	White Store	2.5
10:30 a.m.	White Store	3
10:30 to 11:30 a.m.	White Store	2.0
10:33 a.m.	8 km N of Bingham	0.5
10:40 a.m.	Just W of White Store on US 380	3.3
10:45 a.m.	8 km N of Bingham and 0.25 mi E (Wrye Ranch)	0.2
10:49 a.m.	Just W of White Store on US 380	3.2
10:54 a.m.	14 km E of Bingham along US 380	0.7
10:55 a.m.	0.8 km E of Bingham	1.3
11:00 a.m.	Bingham	1.55
11:00 a.m.	8 km E of Bingham	2.5
11:00 a.m.	6.4 km E of Bingham	2.0
11:00 a.m.	Bingham	0.5
11:30 a.m.	Bingham	1.7
11:40 a.m.	Bingham	0.65
11:50 a.m.	6.4 km W of Bingham	0.25
11:58 a.m.[c]	1.6 km W of Bingham	0.25
12:00 p.m.	Bingham	0.25

Date and Time	Off-Site Location[a]	Recorded Exposure Rate (r h^{-1})
12:02 p.m.[c]	1.6 km E of Bingham along US 380	0.15
Monday, July 16, 1945, continued (after blast at 5:30 a.m)		
1:00 p.m.	Bingham	1.5
1:27 p.m.	6.4 km E of Bingham along US 380	0.95
1:28 p.m.	0.2 km E of White Store on US 380	2.8
1:30 p.m.	White Store	0.15
1:30 p.m.	"Hot Canyon"	6.0
1:35 to 1:57 p.m.	1.6 to 4.8 km E of Searchlight Station L-8	0.5 to 3.8
1:47 p.m.	11 km E of Bingham along US 380	1.6
1:54 p.m.	2.4 km E of Bingham on US 380	1.5
2:00 p.m.	At Bingham	0.5
2:00 p.m.	Rte. 146 just E of junction with Rte. 161	6.0
2:13 p.m.	8 km N on Rte. 146 from junction Rte. 161	2
2:30 p.m.	6.4 km W of Bingham along US 380	0.16
2:30 p.m.	0.27 km E of Sedillo	0.27
2:30 p.m.	Coker Ranch	0.22
2:40 p.m.	9.7 km NE of Bingham on Rte. 161	3.5
2:46 p.m.	13 km NE of Bingham on Rte. 161	7
2:47 p.m.	0.27 km W of Coker Ranch	0.26
2:50 p.m.	Lucero Ranch	0.24
3:00 p.m.	S side of Rte. 161 near junction with Rte. 146	7.0
3:42 to 3:50 p.m.	11 to 21 km W of Vaughn on Rte. 60	"off scale"
4:30 p.m.	Cedarvale	0.11
4:48 p.m.[c]	1.6 km W of Cedarvale on Rte. 42	0.11
4:53 p.m.[c]	4 km mi W of Cedarvale on Rte. 42	0.15
4:59 p.m.[c]	7.2 km mi W of Cedarvale on Rte. 42	0.13
7:01 p.m.[c]	1.6 km E of Willard on Rte. 60	0.11
10:30 p.m.	White Store	0.25
Tuesday, July 17, 1945 (the day after the blast)		
11:39 to 11:54 a.m.[c]	25 to 39 km W of Corona toward Claunch	0.10 to 0.15
12:01 to 12:10 p.m.[c]	8 to 0 km E of Claunch on Rte. 42	0.11 to 0.18
12:14 to 12:21 p.m.[c]	3.2 to 9.7 km S of Claunch	0.11 to 0.19
12:26 to 12:54 p.m.[c]	14 to 40 km S of Claunch	0.11 to 0.30
1:05 to 1:09 p.m.[c]	9.7 to 5.6 km N of Bingham	0.11 to 0.18
2:00 p.m.	Bingham	0.10
3:00 p.m.	White Store	0.10
3:10 to 3:30 p.m.	4.8 to 18 km N of Vaughn on Rte. 285	0.1 to ">> 0.1"
3:30 p.m.	8 km N of Bingham on Rte. 41 toward Monte Prieto	0.19
3:30 to 4:02 p.m.	1.6 to 26 km N of Vaughn toward Encino	> 0.1
4:30 to 6:00 p.m.	24-40 km N of Bingham on Rte. 41 to Monte Prieto	0.19 to 0.30
5:50 to 6:36 p.m.	42-47 km E of Broadway (Trinity access) on US 380	0.11 to 0.5
6:30 p.m.	"Hot Canyon"	0.5
7:30 to 8:00 p.m.	8 to 0 km N of Claunch on road from Gran Quivira	0.10 to 0.19

[c] Measurement time estimated based on odometer readings and times specified for nearby measurements.

Evacuation Policy and Decision Making

Shortly before the Trinity blast, surface winds were blowing toward the North shelter (Hoffman, 1946). About 12 min after the shot, a "Watts' meter" at North shelter indicated a rapid increase in radiation intensity because of a faulty zero setting (Hoffman, 1946, Hoffman, 1947, Maag and Rohrer, 1982). When a remote ionization "sentinel" indicated a rapid increase in radiation, immediate evacuation of all personnel at that shelter was advised. Some personnel evacuated with such urgency that their cars were riding their hubs when they reached Base Camp 25 km south (Lamont, 1965). While film badges worn by personnel in the shelter showed no exposures over 100 mr, the subsequent detection of radioactivity in the area was seen as evidence that part of the cloud had passed over the area, but deposited little radioactivity on the ground (Maag and Rohrer, 1982, Hacker, 1987). Gamma intensities of 10 to 20 mr h^{1} were measured around North shelter two hours after evacuation (Bainbridge, 1976).

Most of the Army evacuation detachment and five radiological safety monitors that were stationed near Guard Post 2 northwest of ground zero remained there until a platoon was sent to Bingham while monitors surveyed that area (Maag and Rohrer, 1982). When the chief monitor learned of exposure rates as high as 3.3 r h^{-1} at Bingham, Adobe, and White Store, he projected that total exposures in that region might approach the allowed limit. The exposure rate of 6.5 r h^{-1} taken 4 mi east of Bingham at 8:49 a.m. was judged to be "getting close to the evacuation limit."[i] A message was sent by courier to Base Camp that integrated gamma doses had been projected at 90% of tolerance (Hoffman, 1947, Hacker, 1987). Medical experts were summoned, exposure rates decreased as the dust dispersed and settled, and no evacuation of the area was conducted. The evacuation detachment was dismissed at 1:00 p.m. on shot day, "when it became evident that evacuations would not be undertaken" (Maag and Rohrer, 1982).

After the recording beta-gamma m at Carrizozo went off scale around 4:20 p.m. on test day, scientists and military officials considered whether Carrizozo should be evacuated. They held off on that action, though, pending some additional monitoring ,and within an hour, fallout readings dropped; officials thus concluded that the radioactive cloud had passed over, and ordered no evacuations (Hoffman, 1946, NTA, 1946, Lamont, 1965, Hacker, 1987). As the cloud drifted beyond the 15 mi radius, north of Bingham and around Carrizozo, monitors often overreached the limits of radio communication with Base Camp (Bainbridge, 1976). As officials at Base Camp were advising Washington that the danger from radioactive fallout was diminishing, they were out of communication with monitors who were measuring fallout in areas as distant as 112 mi to the north (Lamont, 1965).

[i] Notes taken by radiation monitors Robert R. Leonard and W.J. McElwreath, July 16, 1945. LANL Archives Collection A-84-019, Box 8 Folder 1.

Historical records indicate that pressure to maintain secrecy and avoid legal claims led to decisions that would likely not have been made in later tests. Even though exposure rates, total exposures, and alpha count rates exceeding pre-established limits were measured and projected, a "cover story" was in place that would have provided an avenue for relatively inconspicuous evacuation of selected residents, and evacuation personnel, vehicles, shelters, and supplies were on standby, no evacuations of members of the public were conducted.

In a July 31, 1945 War Department memorandum to Dr. Louis Hempelmann (reproduced in Hempelmann, 1947), Lt. Daniel Dailey of the Corps of Engineers refers to requests from Hempelmann that "the health of persons in a certain house near Bingham, N.M. be discretely investigated." During the two years following Trinity, at least seven visits were made to the Ratliff ranch by LANL and MED medical personnel, health physicists, and Army Intelligence agents, "under suitable pretext" to check on the visible condition of the residents (Hempelmann, 1947, Hoffman, 1947). Even after the atomic bombs had been dropped, the atomic bomb project and the roles of LANL and Trinity had been described publicly, and the need for secrecy diminished, the reasons for these investigations were not disclosed to residents.

Monitoring practices and protective action decision processes after the Trinity blast were clearly focused on the immediate hazards of radiation exposure. In the health physics community of the MED "the thinking had not yet focused on possible long-term effects" (Pierre, 1972, Hacker, 1987, Stannard, 1988). Medical surveillance of ranchers was limited to casual observation of external appearances and veiled, non-specific, questioning regarding any health complaints. Although concern was voiced for the health status of at least one family, no evidence was found of steps being taken to reduce exposures to ranchers who continued to live in the fallout zone after July, 1945, in spite of the fact that the soil and the grasses eaten by grazing livestock were particularly radioactive in the area of Hot Canyon. In retrospect, Hempelmann acknowledged that "a few people were probably overexposed, but they couldn't prove it and we couldn't prove it. So we just assumed we got away with it" (Hempelmann and Henrickson, 1986).

After the Trinity test, LANL scientists estimated effective rates of decay and total (external) doses delivered for several public areas (Hoffman, 1947). LANL scientists defined the "geometrical dose" as the integrated dose under the maximum exposure rate that preceded the steady decay (Hoffman, 1947). The geometrical dose was seen to represent "high intensity, short duration dose" that "can be a severe health hazard because it is delivered in a short time interval." The integrated dose used by LANL scientists in 1945 did not include the area under the maximum, but corresponded to the "long, low intensity decay that follows [the maximum]" out to a point in time 14 days after the blast (Hoffman,

1947). The maximum tolerable values of geometrical dose and integrated gamma ray dose for the entire body over a period of 14 days were 50 and 75 R, respectively (Hoffman, 1947).

Table 10-2 shows the geometrical doses, integrated doses, and total doses (geometrical plus integrated) that were reported by Hoffman (1947) for Hot Canyon, White Store, and Bingham. Correction factors for shielding by house structures were based on measurements in Los Alamos (wooden frame) and Bingham (adobe) houses on July 19 and August 17, 1945, respectively (Hoffman, 1947). Based on monitoring done on and beyond the day after the blast, LANL scientists estimated doses at the Ratliff residence (Hempelmann, 1947). For the first 14 days after the blast, the geometrical dose was estimated to be 15 R, the dose from the ground 32 R, and the total accumulated dose (waist high) 47 R-– considered to be a factor of 33 above the tolerance. Radioactivity at the nearby Wilson ranch was estimated to be 75% that of the Ratliff ranch (Hempelmann, 1947).

Table 10-2. External gamma ray exposure values calculated for several public areas after the Trinity test by LANL scientists (Hoffman ,1947)

Location	Geometrical Dose (R)	Integrated Dose (R)	Total Dose after 14 d (R)
Hot Canyon			
On the ground[a]	24	115	139
Corrected for house shielding[b]	24	62	88
Corrected to torso level[c]	15	41	56
Torso level, no house shielding[d]	28	76	100
White Store			
On the ground	8.4	21.8	30.2
Corrected for house shielding	8.4	11.8	20.2
Corrected to torso level	4.2	5.8	10
Torso level, no house shielding	7.8	10.7	19
Bingham			
On the ground	3.3	24	27.3
Corrected for house shielding	3.3	0.3	17.3
Corrected to torso level	1.7	6.5	8.1
Torso level, no house shielding	3.1	12	15

[a] Estimated at 10 cm above the ground surface.
[b] Gamma dose reduced by 46% to account for shielding by an adobe house.
[c] Dose at torso level estimated to 50% of the dose at 10 cm above ground level during the two weeks.
[d] "Corrected to torso level" values divided by 0.54 to estimate torso level with no house shielding.

Trinity Fallout Assessments Performed by Others

Exposure rate contour lines based on the data collected by the town monitoring crews in 1945 based on modeling by the Weather Service Nuclear Support Office (Quinn, 1987) and extended by Lawrence Livermore National Laboratory (Cederwall and Peterson, 1990) are presented in Figures 10-18 and 10-19. The lines in Fig. 10-18 that extend roughly east-west at five distances from ground zero indicate

approximate locations of the edge of the cloud at times from two to 14 h after the shot. The extensions of the fallout contours in Fig. 10-19 show the contamination leaving New Mexico into Colorado and the northwest portion of Oklahoma.

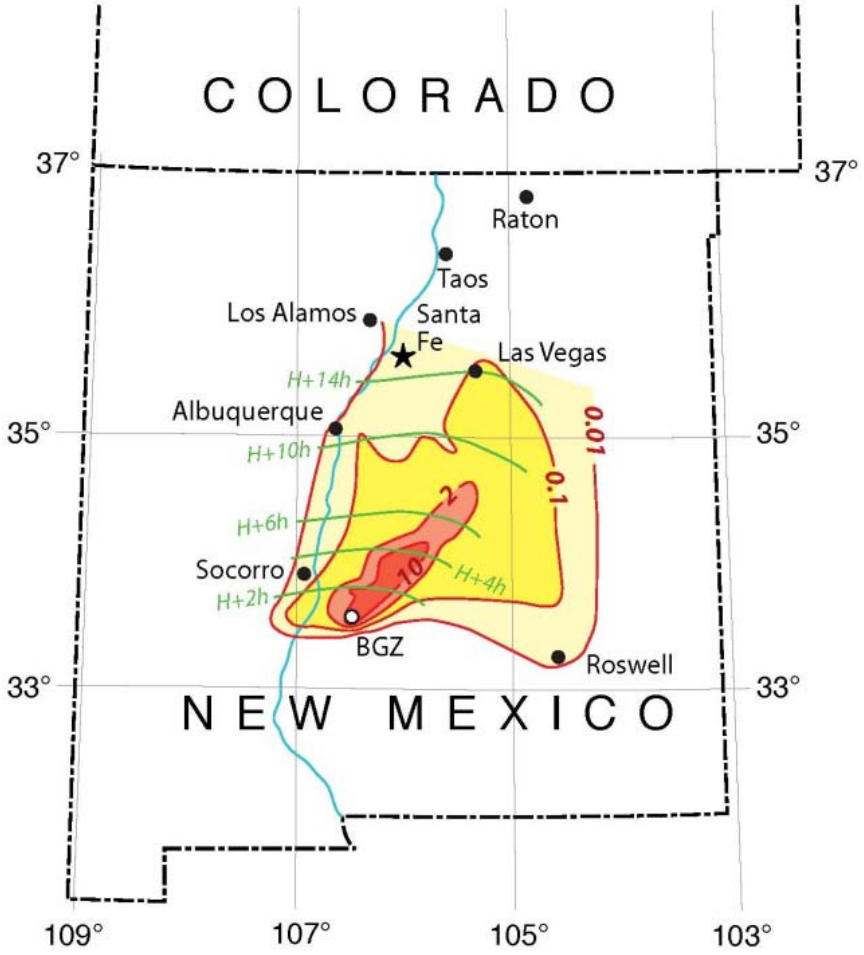


Fig. 10-18. The 0.01, 0.1, 2, and 10 R h^{-1} contours from the Trinity test at t + 1h, as analyzed by the Weather Service Nuclear Support Office (WSNSO)(Quinn, 1987). BGZ = ground zero.

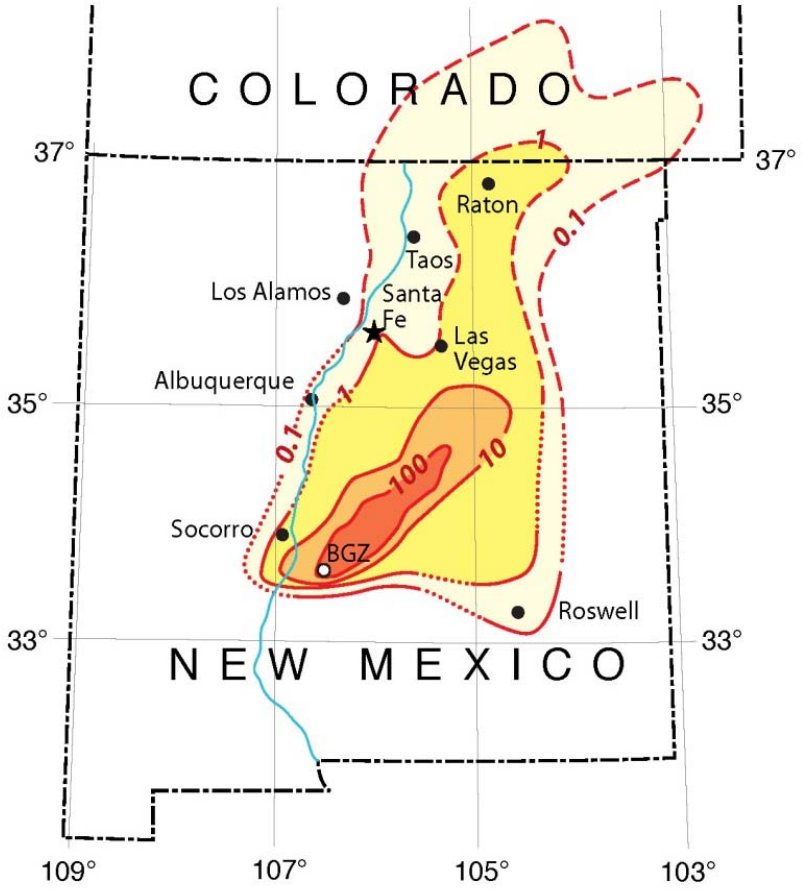


Fig. 10-19. Extension of Trinity fallout pattern as exposure rate, mR h-1 at t + 12 h, based on WSNSO analysis (Quinn, 1987) extended (dotted lines) with LLNL modeling (Cederwall and Peterson, 1990)

A source term for the Trinity event was calculated by scientists at Lawrence Livermore National Laboratory (Hicks, 1985), and fallout patterns were reconstructed on behalf of the USDOE's Off-Site Radiation Exposure and Review Project (ORERP) (Quinn, 1987). Unlike the nuclear explosions at the Nevada Test Site, doses have not been reconstructed for the Trinity event, primarily because of the scarcity of data (Anspaugh, 2000).

Evaluations of public exposures from the Trinity blast that have been published to date have been incomplete, in that they have not reflected the internal doses that were received by residents from intakes of airborne radioactivity and contaminated water and foods. Some unique characteristics of the Trinity event amplified the significance of these omissions. Because the Gadget was detonated so close to the ground, terrain features and wind patterns caused "hot spots" of radioactive fallout. The lifestyles of local ranchers led to intakes of radioactivity via water, milk, and homegrown vegetable consumption. Since

members of the public who lived less than 20 mi downwind were not relocated, the resultant internal radiation doses could have posed significant health risks for individuals exposed after the blast. As a result, internal radiation doses could have posed significant health risks for individuals exposed after the blast.

Gaps in Information about the Trinity Test

In retrospect, pioneer health physicist J. Newell Stannard identified two main gaps in descriptions of Trinity event (Stannard, 1988). The first deals with characterizing residual plutonium, which was present because the efficiency of the device was not 100 percent. The Trinity Gadget contained 6 kg of ^{239}Pu as its sole fissile material (USDOE, 2001). The 21 kt yield of the blast (USDOE, 2000) corresponds, at 1.45×10^{23} fissions per kt (Glasstone and Dolan, 1977) to 3.05×10^{24} atoms or 1.21 kg of ^{239}Pu fissioned, indicating that approximately 4.8 kg of ^{239}Pu remained unfissioned, and was dispersed in the environment. It was present in the crater, and partly scattered around the environment in the fallout. Monitors did find some plutonium (it was not measured very carefully near shot time), but its presence was hinted at in the initial surveys (Stannard, 1988). The instruments used by field monitoring teams were later acknowledged to be incapable of measuring alpha contamination in the environment to the desired sensitivities (Hoffman, 1947). A full-scale survey of the Trinity site was not conducted until three years later, by a group from the UCLA Medical School.

The second gap in information is the lack of any measures for detecting internally deposited radionuclides, such as bioassay, nose swabs, etc. At the time at LANL, nose swab collection and analysis was the main technique for monitoring for inhalation of radioactive material, including in D-Building, where the plutonium hemispheres for the Trinity device were manufactured (Hempelmann and Langham, 1953). There certainly were instances of airborne radioactivity inhalation by members of the public who were in the path of the Trinity cloud or were near deposited radioactivity that was resuspended, and water and food products were also contaminated. The Ratliff home in Hot Canyon, for example, used its tin roof to collect water into a cistern that served as the family's drinking water supply, which was a common practice in the area (Allen, 2008). There was also rain in the area the night after the shot, meaning that deposited radioactivity was likely carried into the Ratliffs' drinking water (Appendix II in Hoffman, 1947).

Some Lessons about Off-site Impacts Learned from the Trinity Test

The Trinity test taught scientists that detonating a nuclear explosive device close to the ground will increase the radioactive fallout. Detonating devices at higher elevations results in the dispersion of less radioactivity while yielding more blast power. Based on the Trinity ex-experience, and later tests

conducted in the Pacific during 1946 and 1948, the potential for exposure of workers and members of the public to fallout became known and appreciated (Anspaugh, 2000).

Scientists also learned that "hot spots" are important phenomena when radioactive clouds disperse, and that their occurrence can be influenced by local terrain features and air flow patterns.

The Trinity site was judged to be too small for additional atomic tests to be conducted. General Groves concluded that the Trinity test site was "too small for a repetition of a similar test of this magnitude except under very special conditions" (Hacker, 1987). He proposed finding a larger site, "preferably with a radius of at least 150 mi without population" [compared to about 15 mi at Trinity] for any future test.

Follow-Up Studies of Trinity Fallout

After the Trinity blast, several monitoring teams continued through the remainder of 1945 to periodically traverse roads to the northeast of the site to measure and record exposure rates. Records of survey trips were found for excursions on 12 additional days in July, eight in August, two in November, and four in December (Hoffman, 1946, NTA, 1946, Hoffman, 1947).

In August, 1947, scientists from the University of California, working with Wright Langham from LANL, conducted a limited survey of a 26,000 ha (100 mi^2) area near the Trinity Site (Overstreet et al., 1947). Between 1949 and 1978, teams from UCLA and the U.S. Environmental Protection Agency (USEPA) published reports of studies of larger zones of local Trinity fallout (Warren and Bellamy, 1949, Bellamy et al., 1951, Gillcoly et al., 1951, Leitch, 1951, Nishita et al., 1957, Douglas, 1978). The earliest UCLA surveys were limited to beta-gamma measurements. Measurements of gross alpha radioactivity in airborne particles (assumed to be plutonium) were first reported in 1951, as were alpha measurements of chemically separated plutonium from plants and soil. The first of these studies to include isotopic analyses of plutonium in environmental media (soil and air) was published by Douglas (1978) for samples collected in 1973 and 1974, over 28 years after the detonation.

Characteristics of Members of the Public near the Trinity Site

Population, ethnicity, diet, housing, and lifestyle characteristics of residents near the Trinity test site around 1945 were described based on, except where noted otherwise, interviews of current residents and historians (Allen, 2008) and information from reviewed documents. Based on interviews of local residents and historians, the typical ethnic compositions of ranchers, sheepherders, and cowboys near the Trinity Site around 1945 were estimated to be as shown in Table 10-3. Both ranchers and town residents used the most readily available construction materials. As shown in Table 10-4, adobe was by far the

most common building material for homes and work places. Barn roofs were typically mud, while home roofs were usually metal to facilitate water collection. In towns such as Carrizozo, most buildings were adobe, but homes made of wood frame construction and bricks were also present.

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Table 10-3. Estimated distribution of ethnicities for residents near the Trinity Site circa 1945 based on LAHDRA interviews (percentages)

Class of Persons	Anglo[a]	Spanish	Native American
Ranchers	90	10	0
Sheepherders	0	100	0
Cowboys	80	20	0

[a]Non-Hispanic white persons

Table 10-4. Estimated distribution of construction types for buildings near the Trinity Site circa 1945 based on LAHDRA interviews (percentages)

Building Type and Setting	Adobe	Wood	Stone	Brick
Ranch homes	85	10	10	0
Homes in towns	75	22	1	2
Ranch workplaces	80	15	5	0
Workplaces in towns	75	23	0	2

During daylight, ranchers and their hired hands would typically be outside working. Breakfast would typically be eaten while it was still dark so work could begin at first light. Meals would have been eaten inside. Since the Trinity test occurred during the summer, children would also have been outside during daylight hours, either working or playing. While ranch wives spent the bulk of their time outdoors tending to laundry, gardening, or helping with the livestock, wives typically spent more time inside than men, preparing meals, canning food, and processing milk.

Cattle and sheep were commonly raised by ranchers in the area, and each ranch typically had horses, chickens, and a garden. Some ranchers also kept hogs. The Ratliff ranch maintained a herd of 200 goats and some turkeys and donkeys (Hempelmann, 1947, Hoffman, 1947). A long-time resident of the area indicated that these goats were raised for their hair, not their milk. If drought caused lack of forage, the livestock was sold.

Ranchers and their hired hands had similar diets. Ranchers in the area typically collected rain water off metal roofs into cisterns, as shown in Fig.10-20, as their source of drinking water. Local ground water

contained excessive mineral content that made it unsuitable for human consumption, but it was used to water livestock. Beans and potatoes were grown in vegetable gardens, but were often supplemented with purchases made in town. Flour, sugar, and other staples were bought in town. Produce, including peas, root crops, squash, and corn, was grown in gardens. Moreover, some ranchers had fruit trees. Produce that was not eaten fresh was canned in glass jars, with the goal of having enough to last the family through to the next harvest. The primary fresh meat sources were deer and chickens, which also provided eggs. If the ranchers ate any beef, it was most likely from grown calves from their dairy cows. Virtually all ranchers kept a dairy cow, and ranch wives processed the milk to make other dairy products used on the ranches.

Fig. 10-20. A system for collection of water off the roof of a residence on the Black Hills Ranch, formerly the Nalda Ranch, east-northeast of the Trinity Site. The cistern to the left, which was damaged by the Trinity blast and then repaired, is still in use today.

The ranches near the Trinity Site did not have electricity until after the War, but most had an icebox. Ice was purchased in town and stored underground at the ranch houses. Some ranchers might have had butane-powered refrigerators or coal-oil-powered refrigerators and stoves. Town dwellers bought their groceries, including milk products, from grocery stores. Town residents had electricity and refrigerators, and water was piped to their homes. Ranchers and historians have little knowledge of local ranchers who drank goat milk, except for one man who reportedly purchased goat milk in Belen, New Mexico. There

has been no published study of the internal radiation exposures for residents downwind of the Trinity test from pathways such as ingestion of cistern water that collected fallout from the roof. Such a cistern was observed at the Ratliff Ranch in "hot canyon."

Conclusions Regarding Pubic Exposures from the Trinity Test

All evaluations of public exposures from the Trinity blast published to date have been incomplete in that they have not reflected the internal doses received by residents from intakes of airborne radioactivity and contaminated water and food. Some unique characteristics of the Trinity event amplified the significance of those omissions. Because the Fat Man device was detonated so close to the ground, members of the public lived less than 20 mi downwind and were not relocated, terrain features and wind patterns caused "hot spots" of radioactive fallout, and lifestyles of local ranchers led to intakes of radioactivity via consumption of water, milk, and homegrown vegetables; it appears that internal radiation doses could have posed significant health risks for individuals exposed after the blast.

The young health physics community had never faced the challenge of monitoring such an extensive environmental release of fission products, activation products, and unfissioned plutonium, and wartime pressures to maintain secrecy and minimize legal claims led to decisions that would not likely have been made in later tests. Different standards of safety were applied to informed project workers than to uninformed members of the public. Project workers knew enough to evacuate areas when high exposure rates were measured, or to take the necessary precautions to minimize exposure, but members of the public did not realize that changes in their behavior were prudent, and project staff did not call for evacuations or protective measures even though predetermined tolerances for exposure rate and projected total exposure had been exceeded.

Too much remains undetermined about exposures from the Trinity test to put the event in perspective as a source of public radiation exposure or to defensibly address the extent to which people were harmed. Beyond omission of internal doses, all assessments released to date are based on monitoring data that have not been subjected to the processes used in modern dose reconstruction studies that include quality checking, cross-checking against other data sources, application of appropriate adjustments or corrections, and uncertainty analysis.

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Chapter 11: Beryllium Use at LANL

Beryllium has been used at LANL since 1943 in various operations related to nuclear reactors and weapons production, including the machining, fabrication and testing of components. French chemist Louis Nicolas Vauquelin was credited with discovering beryllium in 1798 upon formulating beryllium hydroxide. Elemental beryllium, however, was not isolated prior to two independent experiments in 1828. Beryllium occurs naturally only as the ^{9}Be isotope, although five additional isotopes are produced artificially, ^{6}Be to ^{11}Be (IPCS, 1990).

Beryllium is the lightest of all solid and chemically-stable substances, and has an unusually high melting point of 1287 C (HSDB, 2005). The metal has a number of chemical properties in common with aluminum, including a very high affinity for oxygen. A thin film of beryllium oxide forms on the surface of bare metal when it is exposed to air, providing the metal with high corrosion resistance. This film also renders beryllium resistant to water and cold oxidizing acids (IPCS, 1990).

The most important nuclear physical property associated with beryllium is neutron emission upon alpha-bombardment. Beryllium's low neutron absorption properties and its high-scattering cross-section distinguish it as a suitable moderator and reflector of structural material in nuclear facilities. While most other metals absorb neutrons from the fission of nuclear fuel, beryllium atoms only reduce the energy of such neutrons and reflect them back into the fission zone (IPCS, 1990).

Industrial Uses of Beryllium

Interest in, and application of, beryllium grew after the discovery in the 1920s that adding only two percent beryllium to copper would result in an alloy that was six times stronger than copper alone (IPCS, 1990, Becker and Vigil, 1999). As early as 1943, the U.S. nuclear weapons program examined metallic beryllium for use as a possible tamper material. Enough beryllium had been accumulated at LANL by May, 1946 to allow for critical mass experiments (Hanson, 1995). Using large quantities of it in the nuclear weapons program in the 1940s, however, would have exhausted the entire U.S. supply. Beryllium was used as a substitute for gold or natural uranium reflectors in early atomic weapons, thereby saving much weight and money (Hanson, 1995).

Beryllium metal did not become readily available to American industry until 1957. Since that time, beryllium use has used as a glass additive, in ceramics, plastics, camera shutters, submarine cable housings, and dental prostheses, and in beryllium-copper alloys in products such as golf clubs, springs,

pivots, and pinions. Beryllium is also used in the semiconductor, precision electronics, spacecraft, and missile manufacturing industries (IPCS, 1990).

A timeline depicting important events in beryllium's history in general, at AEC/DOE facilities, and at LANL, as well as states of knowledge regarding its health effects, promulgation of guidelines, and regulatory limits, is presented in Table 11-1.

Records Searches for Beryllium Information

The project team has identified few reports written during the period of historical beryllium operations at LANL other than H-Division Progress Reports. Most of the early H-Division reports mention beryllium air sampling in specific LANL buildings, but no details regarding the associated beryllium operations are provided. Several documents located in the LANL Records Center and Report Collection provide summaries of historical monitoring activities associated with beryllium metal machining and firing site operations (Mitchell and Hyatt, 1957, Becker and Vigil, 1999). A Johns Hopkins report (JHSPH, 1999) was recommended to the project team by a former LANL worker, and, after initial contact with the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) office in Española, NM, the team was provided a copy by M. Cadorette, Project Coordinator.

Very little historical stack monitoring data for beryllium have been located by the project team. If stack releases of beryllium were not routinely monitored, indoor air monitoring data might be useful for estimating source terms for beryllium releases to the environment.

Operations Involving Beryllium Release to the Environment

Two types of operations at LANL, machining and firing tests, have resulted in releases of beryllium to the environment. The machining, grinding, sanding, and general handling of beryllium components typically occurred in machine shops or experimental laboratory settings. Dynamic testing has involved using beryllium and other materials in explosive tests in the open air or with various forms of containment or confinement. Industrial hygiene records indicate that activities involving beryllium were performed at 20 different Technical Areas between 1943 and 1980. The main facilities housing beryllium operations within the Original Technical Area are shown in Fig. 11-1. Beryllium metal was processed in the shops and metallurgical labs, and soluble beryllium salts were handled in the chemical labs (JHSPH, 1999).

Table 11-1. Beryllium timeline

1933	First description of acute beryllium disease (Weber and Engelhardt, 1993)
1943	Chemical pneumonia reported in workers extracting beryllium from beryl ore (Van Ordstrand et al., 1943)
1943	U.S. Public Health Service publishes NIH Bulletin 181 stating that beryllium metal is not toxic (Hyslop et al., 1943)
~1944	Beryllium machining began in V Shop at LASL's Original Technical Area
1946	First cases of chronic beryllium disease (CBD) in fluorescent light bulb workers (Hardy and Tabershaw, 1946)
1947	United States Atomic Energy Commission (USAEC) is formed
1949	USAEC establishes a 2 μg m^{-3} occupational exposure limit at their facilities (Eisenbud et al., 1949)
1949	Beryllium machined in V Shop Annex (also known as the "Old Beryllium Shop") at LASL
1952	Exhaust system enlarged in Old Beryllium Shop at LASL
1953	Beryllium is machined in the new beryllium shop at LASL and the old beryllium shop is closed
1957	ACGIH proposes a 2 μg m^{-3} Threshold Limit Value exposure limit (ACGIH, 2006)
1958	USAEC contracts with Brush Wellman for 200,000 lbs of beryllium per year (Stange, 2005)
1959	Health protection in beryllium facilities; summary of 10 y of experience (Breslin and Harris, 1958, Breslin and Harris, 1959)
1971	OSHA adopts the 2 μg m^{-3} permissible exposure limit (PEL) 8-hr TWA (time-weighted average) (OSHA, 2008)
1973	National Emission Standard for beryllium in ambient air 0.01 μg m^{-3} averaged over a 30-d period (USEPA, 2004)
1977	NIOSH recommends a 0.5 μg m^{-3} limit to OSHA, classifies beryllium as a potential occupational carcinogen (USDOE, 1999) based on an increased risk for lung cancer associated with exposure to high levels of beryllium in the workplace before the 1950s (ACGIH, 2006)
1984	First case of CBD at the USDOE Rocky Flats Plant (Stange, 2005)
1998	ACGIH proposes a 0.2 μg m^{-3} TLV®-TWA to minimize CBD and sensitization
1998	USEPA establishes a reference concentration of 0.02 μg m^{-3} based on sensitization and progression to CBD (USEPA, 2009)
1999	USDOE establishes a 0.2 μg m^{-3} action level that triggers workplace precautions and control measures (USDOE, 1999)
2000	Energy Employees Occupational Illness Compensation Program Act (EEOICPA) passed by Congress
2001	EEOICPA makes first CBD claim award (Stange, 2005)
2007	ACGIH proposes a 0.05 TLV®-TWA and a 0.2 TLV®-STEL (short term exposure limit) (NRC, 2008)

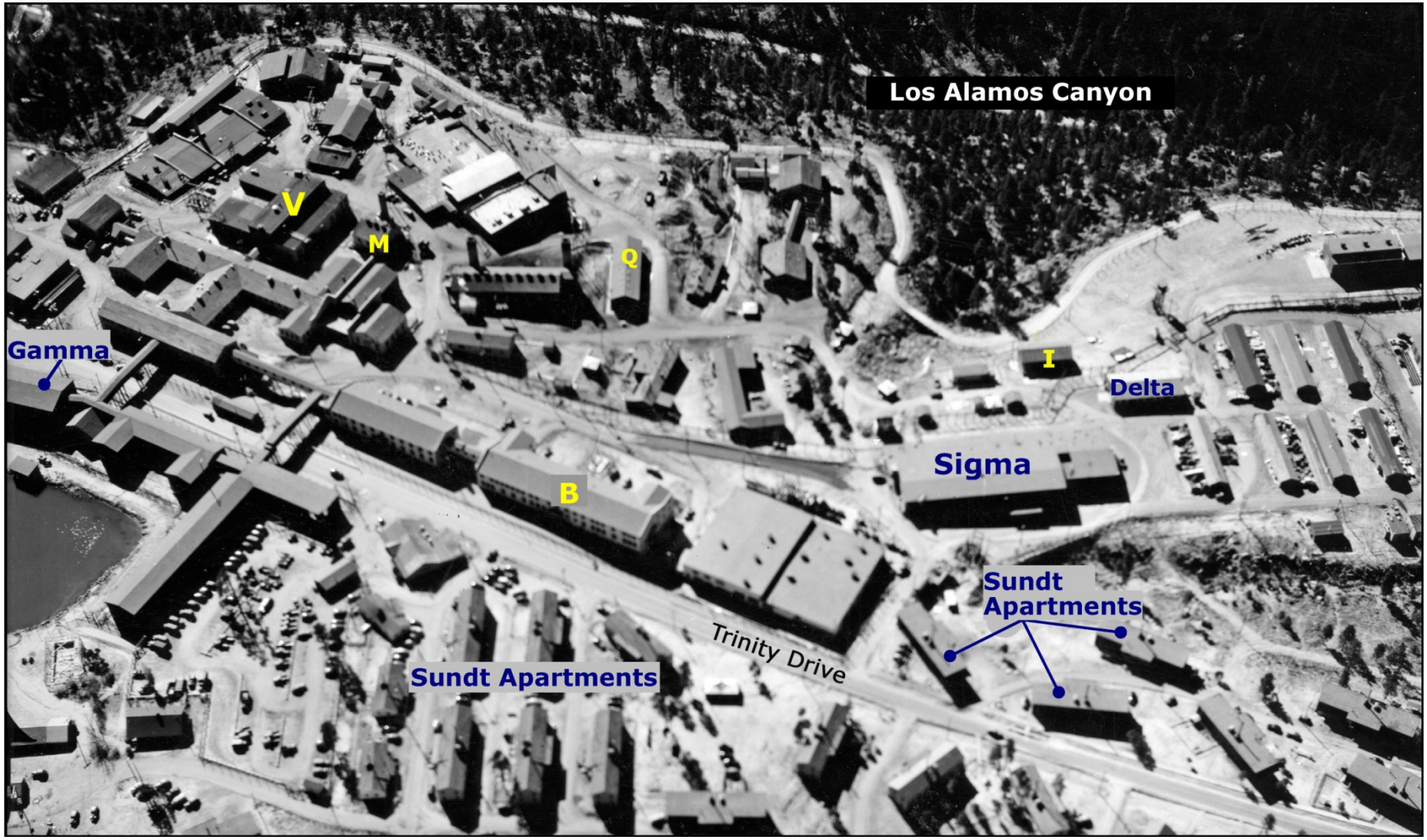

Fig. 11-1. December, 1946 view, looking south, of the Original Technical Area, indicating buildings that had significant beryllium involvement identified: Buildings Gamma, V, and M on the left; B and Q in the center; and Sigma, I, and Delta toward the right. *Based on photo LAHM-P1990-40-1 courtesy of the Los Alamos Historical Society.*

Machining and Component Production Operations

The first production job assigned to the LANL metallurgy groups involved manufacturing specially shaped high-density beryllium oxide bricks required for the Water Boiler reactor. These bricks were produced by hot-pressing beryllium oxide powder into a graphite die or mold of suitable shape. The die and contents were heated to approximately 1,700 C using an induction coil connected to a high-frequency converter under a pressure of 1,000 psi. This process consolidated the semi-plastic beryllium oxide powder into a dense coherent mass in the shape of the die. Occasionally, the bricks had to be ground to a precise size to meet critical dimensions (Smith, 1945).

Until 1948, beryllium was machined in the center of a large machine shop called V Shop located in V Building at TA-1, the Original Technical Area, TA-1 (JHSPH, 1999). Flexible exhaust ducts were placed near the cutting tool, and the captured dust was exhausted into the shop's atmosphere. Because of the use of coarse fiberglass filter media, the Industrial Hygiene Group recommended that the filtered air be exhausted outside the shop.

In 1949, an addition was built onto the main shop for machining only beryllium. All machines were equipped with local exhaust hoods. Each machine hood was exhausted by a blower-filter unit equipped with a wool-felt filter. The air was exhausted outside the building through a common stack. The quantity of air exhausted by each unit was approximately 200 $ft^3\ min^{-1}$. In 1951, the beryllium concentrations in stack effluent ranged from 0.1 to 2.0 $\mu g\ m^{-3}$ (JHSPH, 1999).

In 1952, the local exhaust system was enlarged to provide a larger quantity of air for each machine, and to add an additional lathe and mill to the shop. The blower was capable of exhausting 2,000 $ft^3\ min^{-1}$ through the five local exhaust hoods in the shop, thus providing approximately 400 $ft^3\ min^{-1}$ for each hood. A cloth tube filter was installed outside the old beryllium machine shop to maximize collection efficiency for air cleaning prior to release to the environment. The unit consisted of two steel chambers, each containing 32 cloth tubes (cotton bags containing asbestos floc as a filter aid), operating continuously with a total capacity of 2,000 $ft^3\ min^{-1}$. The collection efficiency determined by isokinetic sampling during normal machining operations was 98.8%. The mass median diameter particle size in samples collected with a cascade impactor in the duct before the filter was 4 microns (μm) (Mitchell and Hyatt, 1957).

In August, 1953, the shop was closed, and all machines and equipment were cleaned to prepare for the move to a new shop building at TA-3, SM-39 (JHSPH, 1999). Operations in the new beryllium shop

started in October, 1953, and included two lathes, a mill, a surface grinder, and an index mill used as a drill press, all in hood enclosures. The cloth tube filter was moved to the filter room above the machine shop in the new building. A dynamic separator was installed before the cloth tube filter and dampers were installed on all machine hoods. Orlon bags with no filter aid were used instead of cotton bags with asbestos floc. The theoretical collection efficiency increased to 99.9%, but the Orlon bags were not as effective (Mitchell and Hyatt, 1957).

Continuous stack samples were collected downstream of the dust tube filter in both the old and new beryllium shops. Of the 309 samples collected between 1952 and 1956 (44 from the V Shop and 265 from the SM-39 Shop), 53% were below 0.05 $\mu g\ m^{-3}$ (the method detection limit), 67% were below 0.10, 77% were below 0.2, 94% were below 1.0, 99% were below 2.0, and 100% were below 25 $\mu g\ m^{-3}$.(LASL, 1969, 1970)

Although no tolerance for beryllium stack discharge had been recommended, based on the results from the exhaust stacks and atmospheric dilution, the Industrial Hygiene Group at that time indicated that the neighborhood tolerance of 0.01 $\mu g\ m^{-3}$ was never exceeded (Mitchell and Hyatt, 1957).

Beryllium work was also initially performed at the Delta, Gamma, I, M, and [old] Sigma buildings at TA-1. Work activities at old Sigma included extrusion, welding, heating beryllium in a furnace, and flame plating beryllium onto substrates. Beryllium metal was welded and machined at Delta building, and beryllium oxide materials were used at M Building. V Shop was a foundry and machine shop, at which a variety of metals, including beryllium, were processed (JHSPH, 1999)

As summarized in Table 11-2 and Table 11-3, industrial hygiene records indicate that sampling for beryllium was conducted in numerous buildings at TA-3 and at 19 other Technical Areas. The Sigma Complex at TA-3 is made up of three large buildings and several smaller buildings, totaling over 200,000 ft^2. These facilities, built in the 1950s and 1960s, house laboratory areas for synthesizing materials and processing, characterizing, and fabricating materials such as beryllium, uranium, thallium, and aluminum alloys. The Sigma Complex is home to two groups of the Materials Science and Technology Division: Ceramics (MST-4) and Metallurgy (MST-6).

The three main buildings of the Sigma Complex are:

- Sigma Building (SM-66)– built in 1959 and 170,000 ft^2 in size;
- Rolling Mill Building (SM-141)– built in the early 1960s and covering 20,000 ft^2; and
- Press Building (SM-35)– built in 1953 and 10,000 ft^2 in size.

Table 11-2. Beryllium operations at TA-3 buildings

Bldg No.	Building Name	Beryllium Operation
SM-16	Van de Graaff Lab	Sanding
SM-29	New CMR Bldg	chemical synthesis, vaporization, purification
SM-30	Warehouse	Unknown
SM-39	Shops Bldg	machining, milling, brazing, heat treating, cutting
SM-32	Center for Material Science	Unknown
SM-43	Admin Bldg	foils, mirrors, BeO rods
SM-49	Physics Bldg	thin foils
SM-66	New Sigma Bldg	Casting, etching, brazing
SM-141	Rolling Mill Bldg	Coating
SM-184	Old Occupational Health Lab	Unknown
SM-218	Magnetic Energy and Storage	Unknown
SM-287	Scyllac Bldg	Unknown

Source: JHSPH, 1999.

Table 11-3. Beryllium operations at Technical Areas other than TA-1 and TA-3

TA No.	Technical Area Name	Beryllium Operation
TA-6	Two-Mile Mesa	Foils
TA-8	Anchor Site West	storage of BeF and BeO
TA-9	Anchor Site East	BeF fusion furnace
TA-14	Q Site	test firing
TA-15	R-Site	test firing with kg quantities of Be
TA-16	S-Site	laundry, burn pit
TA-18	Pajarito Site	Processing Be-U blocks and BeO rods, ultrasonic cleaning
TA-21	DP Site	Machining, milling, arc melting, palletizing
TA-33	HP Site	Machining using a method X machine
TA-35	Ten Site	high temperature Be salts
TA-39	Ancho Canyon	test firing
TA-40	DF Site	milling, test firing
TA-41	Icehouse	test firing
TA-46	WA Site	Heating
TA-53	LANSCE	targets and beam stops
TA-11	K Site	Unknown
TA-43	Health Research Lab	Unknown
TA-48	Radiochemistry	Unknown

Source: JHSPH, 1999.
BeF = beryllium fluoride; BeO = beryllium oxide; Be-U = beryllium uranium alloy

One-third of Sigma Building space contains the mechanical and ventilation equipment necessary to protect employee health and safety. The remaining area includes laboratories, offices, and administrative areas. The Rolling Mill Building contains laboratories for beryllium processing, powder metallurgy, and ceramics and rapid solidification research. The Press Building houses a 5,000-ton capacity hydraulic press with a 12-foot maximum opening and hazardous materials research laboratories (LANL, 1995).

Two 1992 files regarding permits for beryllium operations mention historical beryllium cutting operations at DP West Site's Building 5 in the 1960s and possibly 1950s, and existing beryllium operations in Sigma building (TA-3-66), TA-16-450, and TA-55-4. The operations at Sigma Building and TA-16-450 had existed since the 1950s (Gutierrez, 1992, Tiedman, 1992). An H-1 Division notebook discusses procedures for monitoring beryllium in stack effluent from the CMR Building Wing 5 Filter Tower in February, 1954 (Enders, 1954).

Dynamic Testing Operations

Air samples and fallout trays were used to monitor beryllium during explosive tests starting in 1948, although beryllium was involved in relatively few tests until 1954 (Voelz and Jordan, 1974). Becker and Vigil (1999) reviewed the historical beryllium expenditure in dynamic tests conducted by the DX Division at LANL, and present data on known beryllium concentrations in soil at firing sites, as well as beryllium air concentration measurements onsite and beyond LANL boundaries, and beryllium concentrations in swipe samples. Records for beryllium use in dynamic testing activities at LANL date back to 1955, and include shot records in the form of internal LANL memoranda, DX Division office records and published annual beryllium expenditures in LANL Environmental Surveillance reports. /.Beryllium was presumably expended in dynamic testing activities before 1955, although no verifying data has been compiled. The authors assumed that 160 kg of beryllium was used prior to 1955, but no explanation for this estimate is provided.

Becker and Vigil (1999) estimated a total beryllium expenditure of 1,064 kg for the period of 1955 through 1997 (see Table 11-4). Dynamic testing at firing sites was conducted at TA-40, -14, -15, -36, and -39. The evaluation of available records performed by Becker and Vigil (1999) determined that the majority of beryllium expenditure occurred at three firing sites: PHERMEX, E-F, and R-44 -- all located at TA-15.

Table 11-4. Beryllium expenditure at LANL firing sites 1955-1997

Site	Status as of 1999	Beryllium Expended (kg)
R-44 (TA-15)	Closed	346
PHERMEX (TA-15)	Active	332
E-F Site (TA-15)	Closed	321
R-306 (TA-15)	Active	43.6
All other firing sites at TA-15, -36, -39	--	21.4
TOTAL		1,064

Source: Becker and Vigil, 1999.

Using a mass balance approach and the following assumptions, Becker and Vigil (1999) estimated beryllium soil concentrations for three firing sites.

- 160 kg of beryllium expended prior to 1955
- more shots at E-F Site during years prior to 1955

- 2% of beryllium becomes aerosolized
- uniform soil concentration to a depth of six inches

The authors of the study found less beryllium in soil than they predicted, and so provide possible explanations for the discrepancy, such as erosion and non-representative sampling. They postulated that the soil sampling might not have been representative of actual onsite contamination, or that other processes, such as mass movement and erosion, removed contamination from the firing sites.

LANL has conducted open-air dynamic experiments in which weapon components are either detonated or impacted against a target, resulting in beryllium contaminated soil (Sauer et al., 2001). Monthly reports written by the LANL Dynamic Testing Division from December 1975 through December 1987 document fugitive emissions from explosive test shots, including released quantities of beryllium. During this 13-year period, 178 kg of beryllium were released as a result of test shots conducted at TA-15, TA-36 and TA-40. According to the monthly reports, 98% of the total beryllium emissions occurred between 1977 and 1982, and in 1984. However, about one-third of the monthly reports for the 13-year period are missing from the collection identified by the project team, and 75% of the missing reports are from the years 1983, 1985, 1986, and 1987. In the reports that are available, 55% of the monthly values are reported as 0 kg. The average monthly release is 1.65 kg, with a standard deviation of 2.42 kg. The median monthly release is 0.02 kg, the 95% upper confidence limit on the mean is 2.04 kg, and the maximum monthly release is 10.6 kg (for November, 1976).

B-Building Annex

The LANL Director's Office files for 1944 describe a request for four alpha detectors from Chicago for "0.05 d/cc/s" (disintegrations per cubic cm per second) in air in a 14" × 25" duct flowing 800 ft^3 min^{-1} and in other ducts (Bainbridge, 1944). The detector was apparently for B-Building annex, which was used for testing initiators, and was an unmonitored release point for beryllium and polonium.

Information regarding the former B-Building Annex at TA-1 was located in source material for the book *Critical Assembly* (LASL, 1944-1945, Hoddeson et al., 2004). A folder in the LANL Archives contains draft chapters and LANL memos that were referenced in each chapter and describe the gun device and initiator testing. The B-Building annex, called the "wart on B-Building," was authorized by J. Robert Oppenheimer and constructed by the end of March, 1944. It held a 20-mm, remotely fired, anti-aircraft autocannon used for testing scaled-down versions of gun-assembled atomic weapon components, such as initiators. By mid-April, 1944, the annex was in operation. In August, 1944, a box called a "coffin" was authorized that operated at negative pressure and had a gas mask filter on its exhaust. By the end of

September, the gun had been used in nearly 180 experiments, at a frequency of once per day. Chapter seven in *Critical Assembly* does not mention beryllium, nor do the assembled memos, since beryllium was not viewed as a hazardous material in the early 1940s. About 50 lbs per month of beryllium was used for initiator fabrication (LASL, 1944-1945).

Quantities of Beryllium Used at LANL

An estimated 1,064 kg of beryllium was used between 1955 and 1997, and another 160 kg was used prior to 1955 at LANL (Becker and Vigil, 1999). Ninety-four percent of the beryllium was expended at PHERMEX, E-F, and R-44 firing sites, and another 4% was expended at firing site R-306. Detailed information is not available on the remaining 2%, but presumably that amount can be divided among the other firing sites.

According to Becker and Vigil (1999), the greatest annual expenditure of beryllium, in excess of 100 kg, occurred in 1964, and significant beryllium use occurred between about 1957 and 1971 (see Fig. 11-2). Beryllium use since 1985 has been relatively low, with annual expenditures remaining less than 5 kg.

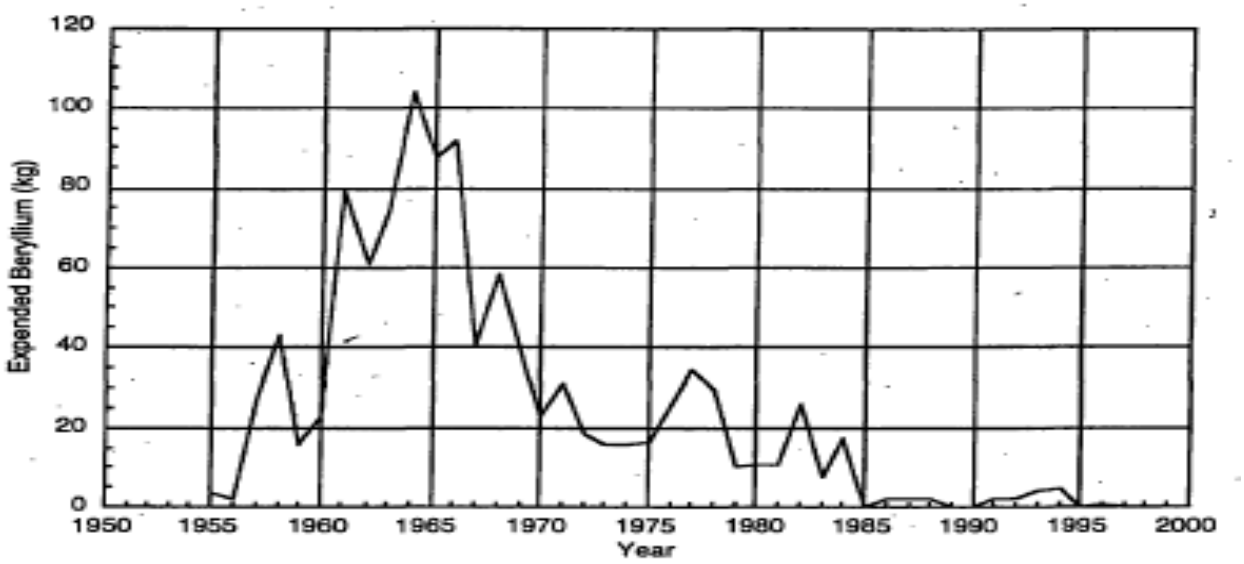

Fig. 11-2. Annual estimates of beryllium expended in DX-Division dynamic testing operations

In a 1977 report, LANL scientists estimated that 2% of the beryllium present in test devices becomes aerosolized during dynamic experimentation (Dahl and Johnson, 1977). Based on this estimate, per LANL records, calculations indicate that approximately 1,200 kg of beryllium remains in the soil near LANL, and approximately 94% or 1,128 kg remains at the E-F, R-44, and PHERMEX firing sites.

Monthly reports written by the LANL M-DO Division document fugitive emissions from explosive test shots conducted from December, 1975 to December, 1987 (LANL, 1975-1987). The emissions data are shown in Table 11-5. The release locations are the explosive test areas at TA-15, TA-36 and TA-40.

Workplace and Environmental Beryllium Monitoring

Beryllium air concentrations have been monitored at LANL for both indoor machining and outdoor firing tests operations since 1948 (Voelz, 1970). Measures to control beryllium exposure were in place at LANL beginning in 1948 based on recommendations from Dr. Harriet Hardy, an occupational medicine pioneer at the Massachusetts Institute of Technology (MIT), who collaborated with the AEC at LANL. LANL's Industrial Hygiene Program was introduced that same year (Mitchell and Hyatt, 1957).

Table 11-5. Beryllium released to the environment by shots at TA-15, TA-36, TA-40

Year	Beryllium (kg)	Beryllium Oxide (kg)
1975	0.1	0
1976	25.54	0
1977	34.7	3
1978	29.2	0
1979	14	0
1980	9.8	0
1981	10.6	0
1982	26	0
1983	5	0
1984	16	0
1985	0	0
1986	2.1	0
1987	2	0
TOTAL	175	3

Source: LANL, 1975-1987

Beryllium Metal Machining

The Industrial Hygiene Group at LANL conducted periodic surveys of beryllium machining operations from early 1948 through August 17, 1951. After September, 1951, daily air samples were collected whenever beryllium was being machined. From September, 1951 through 1955, a sampling rate of 20 L min^{-1} and a filtering velocity of 130 ft min^{-1} with Whatman #41 filter paper resulted in a collection efficiency of 70%. In 1956, a sampling rate of 10 L min^{-1} and a filtering velocity of 65 ft min^{-1} with Whatman #44 filter paper resulted in a theoretical collection efficiency of 99.8%

A continuous air sampler with a sampling rate of 20 L min^{-1} and a filtering velocity of 130 ft min^{-1} using Whatman #4 filter paper was used to monitor beryllium air concentrations for short periods of exposure. The sampler was set to collect hourly general air samples in the vicinity of the machining operations. The reported collection efficiency was 80%. Starting in 1954, the hourly samples were only analyzed when an 8-h breathing zone sample approached the tolerance level of 25 μg m^{-3}.

Air samples collected to assess beryllium concentrations through June, 1950 were collected with an electrostatic precipitator and sent to the University of Rochester for analysis (Mitchell and Hyatt, 1957). Although air samples were analyzed by the Industrial Hygiene Group beginning in June, 1950, samples continued to be collected by the electrostatic precipitator through August, 1951. Starting in September, 1951, samples were collected using a portable pump connected to a sampling head equipped with filter paper. Samples collected after June, 1951 were analyzed using a method based on the fluorescence of morin with beryllium in an alkaline solution (Sax and Kramlich). Beryllium concentrations ranging from 0.05 to 300 μg were adequately detected with this method. Air samples were reportedly analyzed by atomic adsorption in the early to mid 1990s, while samples collected in the late 1990s were analyzed by inductively coupled plasma atomic emission spectroscopy (Becker and Vigil, 1999).

From 1950 to 1953, filter type respirators were occasionally used on special jobs. In some cases the filters from these respirators were analyzed for beryllium content. Analyses of respirator filters used during filter unit cleaning, and used during drilling operations without local exhaust ventilation, showed beryllium concentrations ranging from 300-400 μg m^{-3}.

An experiment performed by the Industrial Hygiene Group in 1951 to determine the greatest sources of exposure during beryllium operations revealed that rough cutting created the heaviest source of dust. One air sample collected in the hood eight inches from the cutting tool while rough cuts were being made on a piece of bar stock yielded a beryllium concentration of 725 μg m^{-3} (Mitchell and Hyatt, 1957).

Routine air samples collected between September, 1957 and June, 1958 at the machine shop were well below permissible levels (LASL, 1957, 1958). A distinct rise in the average beryllium concentration at the beryllium shop in 1957 was tracked to full time work on a crash program to make special beryllium pieces. The number of air samples collected at CMB-6 was also increased greatly during this time frame, in conjunction with a research project trying to determine the best method of joining two pieces of beryllium.

The beryllium machine shop at LANL was cleaned weekly, and surface swipe tests were performed to ensure that loose beryllium dust levels were maintained below 15 μg ft^{-2} (Mitchell and Hyatt, 1957)

Firing Sites

A 1970 report (in the form of a letter) from the LANL Health Division Leader to the Deputy Director of Military Application, USAEC, describes the historical beryllium air sampling near explosive tests at LANL from 1948 to 1959 (Voelz, 1970). While air samples and fallout trays were used to monitor beryllium during explosive tests starting in 1948, beryllium was involved in relatively few tests until 1954. In 1954, beryllium exposure resulted from test firing of beryllium pieces in conjunction with explosives at TA-39, the Ancho Canyon Site. Most of the samples were collected between 1956 and 1959 when all tests occurred at R Site and were conducted by the GMX-4 group. In 1955, Group W-3 conducted an experiment at TA-33 in which a device exploded and large pieces of beryllium were scattered over the firing area. Tests involving beryllium after 1959 were conducted at Ancho Canyon by GMX-6 and at PHERMEX by GMX-11. Table 11-6 summarizes the data described in the 1970 Voelz letter-report. The letter also states that a few of the fallout trays "showed beryllium in the collected material," but no elaboration is provided. The report concludes: "Because of our experience with these results, shots containing beryllium are not monitored regularly but only when some special conditions of testing are planned."

Table 11-6. Beryllium concentrations measured from LANL explosive tests 1948–1959, μg m^{-3}

Site	No. of Shots	No. of Samples (N)	No. of Samples >MDC of 0.05	Maximum Onsite	Maximum Offsite
R-Site	39	156	11	0.66 (0.34) [1]	0.05 [2]
Ancho Canyon	8	24	1	0.004 [3]	NR
PHERMEX	2	NR	0	NR	NR

MDC = minimum detectable concentration; NR = Not reported.

[1] Measured 800 y directly downwind from the shot.

[2] Measured at Ten Site (TA-35).

[3] Measured 150 y from the shot.

Beryllium air sampling was performed by the LANL Environmental Surveillance program in the early 1970s, and again in the 1990s. Samples collected on the roof of TA-59-1 during 1971 and 1972 yielded beryllium air concentrations between 0.06 and 0.4 ng m^{-3} (0.00006 and 0.0004 μg m^{-3}). Quarterly samples of airborne beryllium collected onsite, at the LANL perimeter, and regionally in northern New Mexico in 1990, 1992, 1993 and 1994 as part of the AIRNET program, ranged from 0.002 to 0.061 ng m^{-3}. When quarterly sampling resumed in 1998, quarterly Airnet beryllium values ranged from 0 to 0.1 ng m^{-3}. Area air samples collected in 1998 at two firing sites during dynamic shots ranged from 0.013 to 0.381 μg m^{-3} of beryllium (Becker and Vigil, 1999).

Beryllium concentrations in surface water samples collected from the E-F Firing Site (TA-15) in March, 1985 ranged from <1 – 2 parts per billion (ppb) in the dissolved fraction, and from 1.2 – 11.5 ppb in the suspended fraction.

One of the research interests of the Off-Site Source Recovery Program at LANL is the environmental fate of beryllium released from disposing neutron sources containing beryllium metal that could not be recycled or reused. A 2000 progress report describes the experimental use of beryllium-contaminated soils obtained from LANL Dynamic Experimentation Division firing sites. Two samples (locations not specified) contained 74 and 29 mg kg^{-1} of beryllium (Sauer et al., 2000). Table 11-7 summarizes the soil data from six firing sites (Cokal and Rodgers, 1985, Becker and Vigil, 1999).

Table 11-7. Beryllium concentrations in soil at firing sites, μg g^{-1}

Site	Year	Samples (n)	Range	Mean	Background
PHERMEX	1987	59	1 – 470	31.5	1 – 2.4
PHERMEX	1993	21	<1 – 218	13.4	NR
PHERMEX	1998	18	0.14 – 74	7.1	NR
E-F	1985	9	2.3 – 14.4	NR	NR
E-F	1999	60	NR	1.3	NR
R-44, R-45	1994	44	NR	7.2	NR
TA-39	1995	22	<1.3 – 9.1	NR	NR
TA-40	1995	39	<1.3	NR	NR

NR = Not Reported

LANL and LLNL groups have studied the aerosolization of beryllium from open-air shots (Dahl and Johnson, 1977). Dahl and Johnson (1977) determined that 2% of the beryllium mass became respirable (<10 μm) because of aerosolization. For a shot containing 600 g of beryllium, the beryllium concentration 4,376 y downwind of the shot would be 0.2 μg m^{-3} 15-30 min after detonation for 1-3 min. Shinn et al. (1989) found that 8% of the beryllium mass became aerosolized, and that the beryllium was largely in the form of insoluble, high-fired beryllium oxide. For a shot containing 900 g of beryllium, the respirable beryllium concentration 55 y from the shot was 3.2 μg m^{-3} for 10 min. Measured soil concentrations at three LANL firing sites, however, were less than predicted assuming 2% or 8% aerosolization (Becker and Vigil, 1999), suggesting that aerosolization could be greater than 8% (Sauer et al., 2001).

Beryllium resuspension has been evaluated in three studies, two at LANL and one at Sandia National Laboratories. Sandia researchers estimated a resuspension factor of 1×10^{-7} m^{-1} for wind blown soil (1 g Be per m^2 of soil = 0.1 μg m^{-3} Be in air) (Luna et al., 1983). A LANL researcher predicted that resuspension of beryllium from a firing site could result in worker exposures to 0.6 μg/m^3 of beryllium (Maez, 1997). Measured beryllium concentrations during drilling activities at a LANL firing site, however, were four orders of magnitude lower (Mroz, 1995).

Episodic Releases

In a joint effort with the U.S. Air Force, LANL performed an experiment at Beta Site (TA-5) to evaluate the potential air or ground contamination that might result from burning a plane containing significant amounts of beryllium (LASL, 1957). A piece of beryllium was placed above a large quantity of jet fuel and ignited. Air and soil monitoring results failed to reveal detectable quantities of beryllium at a range of distances downwind of the fire.

Waste Disposal

Small quantities of beryllium residues were among the chemical waste disposed of in Areas G and L at LANL. Waste was disposed of in Areas G and L by placing it in shafts, trenches, and pits excavated in the Bandelier Tuff, at depths up to 65 ft. In late 1985, 18 boreholes to 100- to 135-ft depths were drilled in Bandelier Tuff from the top of Mesita del Buey. Core samples were collected from seven of the boreholes at about 10-ft intervals. Only two of the 70 samples that were collected contained concentrations of metals (specific metals were not identified) above their detection limits. Both were acquired at shallow depths (20 ft or less) at Area L (LANL, 1987). All rags and waste from housekeeping activities in the old and new beryllium shops were disposed of in the burial pit (Mitchell and Hyatt, 1957).

Off-Site Area Monitoring

Air samples were collected quarterly between 1990 and 1994 in northern New Mexico, around the LANL perimeter in Los Alamos, in White Rock and Bandelier National Monument, and within LANL, primarily at TA-52, TA-16 and TA-3 (Becker and Vigil, 1999). The mean beryllium concentration recorded at the off-site locations during this timeframe was 0.014 ng m^{-3}, while the mean concentration reported at the on-site locations was 0.009 ng m^{-3}. Additional sampling was performed at off-site and on-site locations in 1998, and the mean air concentration recorded at all sampling locations during this year was 0.021 ng m^{-3}.

Exposure Guidelines for Beryllium

The U.S. Atomic Energy Commission issued "Recommendations for Control of Beryllium Hazards" in August, 1951 that included three standards: a 2 μg m^{-3} in-plant, 8-hr average beryllium concentration; a 25 μg m^{-3} beryllium air concentration that should never be exceeded; and a 0.1 μg m^{-3} monthly average concentration at the breathing zone in the neighborhood of a plant handling beryllium (Mitchell and Hyatt, 1957).

The current OSHA permissible exposure limit (PEL) for occupational exposure to beryllium is 2 μg m^{-3} (8-h time weighted average). A ceiling limit of 5 μg m^{-3} must not be exceeded during the work shift, except that a 30-min excursion over the ceiling limit is allowed, so long as the air concentration never exceeds 25 μg m^{-3} during the 30-min period (NIOSH, 2003).

The current USEPA Reference Concentration (RfC) for beryllium is 0.02 μg/m^3 (USEPA, 2009). The RfC is an estimate (with uncertainty spanning an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in studies published in 1949 and 1996 (Eisenbud et al., 1949, Kreiss et al., 1996). The Kreiss et al. (1996) occupational exposure study identified a LOAEL (Lowest Observed Adverse Effect Level) for beryllium sensitization in workers exposed to 0.55 μg m^{-3} (median of average concentrations). A cross-sectional study was conducted of 136/139 of the then-current beryllium workers in a plant that made beryllia ceramics from beryllium oxide powder. Measurements from 1981 and later were reviewed that included area samples, process breathing-zone samples, and personal lapel samples (from the last year only). The Eisenbud et al. (1949) study, using relatively insensitive screening methods, suggests a NOAEL (No Observed Adverse Effect Level) of 0.01-0.1 μg m^{-3} in community residents living near a beryllium plant. The LOAEL from the Kreiss et al. study was used for the operational derivation of the RfC because the screening method used in the Eisenbud et al. (1949) study was less sensitive than the method used in the Kreiss et al. (1996) study.

Beryllium Releases and Exposures at LANL

It has been reported that largest number of men at LANL were exposed during beryllium machining, although the most difficult processes to control involved using powdered beryllium and soluble beryllium compounds (Hyatt and Milligan, 1953). Worker exposure to beryllium from dynamic testing was substantially less than that encountered in the machine shop or laboratory settings, primarily because beryllium was present during detonations conducted outside under atmospheric conditions, and because

during detonation and afterwards, workers were confined to a closed control bunker or detained at road blocks set up ¼ mi or more from the firing site (Becker and Vigil, 1999). Post-shot beryllium particle dispersion caused by wind was expected to occur rapidly and to significantly dilute beryllium concentrations present in air at the firing sites. If exposures to beryllium did occur at firing sites, exposures most likely would have occurred during dust resuspension from soil and vegetation during brush removal.

Secondary occupational exposure of workers' families significantly increased beryllium intake through dust when clothing of occupationally exposed individuals were not kept at the workplace, as was usually the case in the 1940s (IPCS, 1990). Eisenbud et al. (1949) reported that short-term beryllium levels of 125 to 2,000 $\mu g\ m^{-3}$ were measured in the indoor air after clothing from employees at a beryllium-producing plant were shaken. The authors estimated that approximately 17 $\mu g\ d^{-1}$ could be inhaled by a person during the laundering of the same clothing. However, documents indicate that LANL provided its machine shop workers with complete protective clothing and adequate showering facilities (Mitchell and Hyatt, 1957). This clothing consisted of coveralls, underwear, socks, and safety shoes. Canvas booties were worn over the safety shoes before leaving the machine shop to go to the tool crib. Likewise, employees working at firing sites wore dedicated work shoes that were removed and kept onsite each evening (Becker and Vigil, 1999).

Medical Surveillance of LANL Workers

Medical surveillance of workers at LANL began in the 1940s (Stefaniak et al., 2003). A memo from Dr. Cleve Beller of LANL dated January 24, 1947 announced that all Sigma Building personnel handling beryllium were examined, or had made arrangements to be examined, by the Health Group (LASL, 1944-1950). A report detailing beryllium use at DX Division Firing Sites (Becker and Vigil, 1999), noted that nine workers in the DX Division were in the beryllium medical surveillance program. None of these individuals reportedly were identified as having chronic beryllium disease or beryllium-associated illness.

An internal memo from Dr. Thomas Shipman of LANL in May, 1951 suggests that the health effects associated with beryllium were unknown to LANL until November, 1947, when Dr. Harriet Hardy of MIT held a meeting to discuss beryllium-related health concerns (LASL, 1944-1950). The result of this meeting was the ceasing of certain beryllium operations (not described), and, from that point forward, using beryllium at LANL was subjected to careful scrutiny.

A series of memos between Dr. Hardy and Dr. Thomas Shipman discussed a case of apparent chronic beryllium poisoning (LASL, 1944-1950). The individual in question worked at LANL from 1946 until

1949, for P Division in Building U, which was documented as being in the vicinity of the beryllium machining shop. However, this individual's exposure potential was not limited to that alleged at LANL; he was also employed at other facilities, including Oak Ridge, which also used beryllium. A memo from Dr. Hardy to Dr. Guy Fortney at Oak Ridge in September, 1964 reported that the beryllium content in this individual's lungs at the time of his time of death was 0.021 $\mu g\ g^{-1}$. Two additional cases of apparent berylliosis among LANL personnel were reported in a February, 1953 memo from Dr. Shipman.

As of June, 1998, 110 workers have been diagnosed with chronic beryllium disease; the majority of these workers are associated with the Rocky Flats and Y-12 (Oak Ridge) plants (Becker and Vigil, 1999). A Former Worker Medical Surveillance Program that included screening for chronic beryllium disease (CBD) was started in 1999 (Stefaniak et al., 2003).

Beryllium Toxicology and Epidemiology

Acute beryllium disease is usually observed at relatively high beryllium exposure levels, has a short period of induction, and is usually resolved within a couple of months of exposure termination. The disease is believed to be an inflammatory response to beryllium, and most regions of the respiratory tract are affected; some reported symptoms include nasopharyngitis, shortness of breath, labored breathing, and chemical pneumonitis (ATSDR, 2002).

Chronic beryllium disease is a systemic granulomatous disorder that predominantly affects the lungs. In general, the occurrence of this disease has been confined to workers exposed to beryllium metal and to less soluble beryllium compounds, such as beryllium oxide. However, there have been cases among residents living near beryllium manufacturing facilities and in families of workers who wore contaminated clothing at home. Chronic beryllium disease is caused by an immune reaction to the inhaled beryllium that is deposited in lung airspaces and retained for a prolonged period. In certain individuals who become sensitized to beryllium, the beryllium in the lungs binds to protein/peptides in the lungs, causing inflammatory cells to accumulate in the lungs, which results in granuloma formation and the fibrosis development. Susceptibility to chronic beryllium disease is believed to have a genetic component (ATSDR, 2002).

A number of large-scale screening studies have examined beryllium workers, and have found beryllium sensitization rates of 1–15% in workers involved in producing beryllia ceramics and nuclear weapons. More than half of the beryllium sensitized workers were diagnosed with chronic beryllium disease. Several studies attempted to establish associations between beryllium sensitization and/or chronic beryllium disease and mean, cumulative, and peak exposure levels and employment duration. In general,

though, no consistent associations were found. Although the data are insufficient for establishing concentration-response relationships, the available occupation exposure studies do indicate exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of 0.5 μg m^{-3}. Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels of beryllium (0.03–0.2 ng m^{-3}) are very low (ATSDR, 2002).

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Chapter 12: Processing and Testing High Explosives at LANL

High explosive research, development, and testing was conducted at more than 25 different LANL Technical Areas (Goldie, 1984, LANL, 1990). Since the 1940s, many new formulations of the conventional explosives HMX, RDX and TNT have been synthesized and tested at LANL (Dobratz, 1995). Other high explosives, such as Baratol, Comp B, Pentolite, Torpex, and Tetryl, were tested at firing sites, such as those at TA-14 (IT Corporation, 1989). The initial plan for the first atomic weapon was for a gun type weapon that would use "slow-burning" propellants. When in July, 1944 it became clear that the weapon would have to be an implosion design due to the presence of the ^{240}Pu isotope in the active material, high explosives became a key component of the plan.

X-Division

The implosion program began in April, 1943 with a proposal by S. H. Neddermeyer on an elementary theory of high-explosives assembly, but there was no established art to follow. Implosion research began as one small group's concern, and then grew into LANL's major problem in the early 1940s. The first implosion tests at LANL took place in an arroyo on the mesa just south of the laboratory on July 4, 1943. The test device consisted of tamped TNT surrounding steel spheres. In April, 1944, G. B. Kistiakowsky became the leader for the implosion program.

Data from photographing the interiors of imploding devices revealed the need for controlled quality of high-explosive (HE) castings. Special photographic techniques were developed at LANL to study the implosion process, such as rotating pyramid and rotating mirror photography, high-explosive flash photography, and flash x-ray photography. The Anchor Ranch range (TA-9) had been designed for implosion research, but a large casting plant and several widely spaced test sites were also needed. Casting plant construction began in the winter of 1943 at S (Sawmill) Site (TA-16). S-Site was staffed almost entirely by men from the Army's Special Engineering Detachment (SED), since finding men with experience handling explosives was nearly impossible (Hawkins, 1961). At the end of the war, there were over 1,000 SED men assigned to the X-Division (Kistiakowsky, 1975).

In July, 1944, a new development in the implosion program involved using explosive lenses that would convert a multiple-point detonation into a converging spherical detonation wave, thus eliminating troublesome interaction. Designing lens molds was a difficult first step, and took several months. In the August, 1944 reorganization, Division X was formed under G. Kistiakowsky to experiment with

explosive fabrication and production. Three groups from the old Ordnance Division (E-Division) in U Building- Implosion Experimentation, HE Development, and S-Site Group were transferred to the new Explosives (X) Division. Implosion dynamics and active core design investigation were assigned to the Weapon Physics (G) Division (Hawkins, 1961).

Explosives Production and Testing

X-Division records indicate that about 20,000 experimental quality castings were produced in an 18-month period, and a much larger number were rejected for quality control reasons. The principal types of HE used were Composition B, Torpex, Pentolite, Baranol and Baratol. Using risers and overcasting to concentrate imperfections and minimize the very dangerous task of machining HE resulted in over 50,000 machining operations without a detonation (Hawkins, 1961). According to Kistiakowsky (1975), tens of thousands of castings were made, primarily of Comp B and Baratol. Baratols, with a higher percentage of barium nitrate (76%) than TNT, was used for the slow component of the lens system, whereas cyclotols such as Comp B (60% RDX: 40% TNT) were used for the fast component (Kistiakowsky, 1975, Gibbs and Popolato, 1980).

As described in Wilder (1973), operations at S-Site consisted of melting HE and pouring it into molds that were shaped based on theoretical calculations. The initial facilities at S-Site were inadequate, especially for machining. As a result, there was continuous new building planning and construction until just before the Trinity test in July, 1945. Casting operations in Building 42 used stainless steel candy kettles that were jacketed and steam heated. The molten explosive was poured from the kettle into a rubber bucket, and then into steel molds. The mold was finished with Cerrotru, a low-melting casting alloy, around a master shape that was supported in the steel weldment. In Wilder's opinion, developing the bomb's explosive component was greatly facilitated by using self-adhesive tape just about everywhere. In addition, Building 27, built in 1945, had larger kettles and the temperature of cooling water could be varied.

After casting, the HE was taken by hand truck to Building 43 to be machined. The equipment in Building 43 consisted of one K&T milling machine and several Delta drill presses. Comp B was machined under water, and Baratol was initially machined dry, but with water later. Building 55 housed the one small high-speed hammer mill used for grinding barium nitrate. Buildings 31, 32 and 33, built in 1945, were machining bays for Fosdick radial-arm drills. As S-Site activities expanded, they moved into V-Site (TA-25). Three methods were used to protect the cast HE from chipping. In buildings 519 and 520, castings were sprayed with the best "Bar Top" varnish available, felt was glued to one of two mating surfaces, and

blotting paper was glued to the sides. Practice assemblies were made in Gamma Building in the main Technical Area, where the floors were padded with wrestling mats. The Trinity bomb was assembled in Building 516. All explosive operations produced great quantities of scrap that was collected daily and burned in the area near Building 260 (Wilder, 1973).

According to Hawkins et al. (1961), S-Site, at its peak, used over 100,000 lbs of high explosives per month. Dr. Kistiakowsky's recollection was that about 25 tons (50,000 lbs) were trucked up the hill per month during the most active HE casting period. X-Division Progress Reports indicate that between 140,000 and 170,000 lbs per month of high explosives, primarily Comp B, TNT and barium nitrate (BN), were used during the months of May, June, July, and August, 1945 (see Table 12-4). Precision molds and machining were required, and, according to Kistiakowsky (1975), there were over 500 machinists and toolmakers available during the peak period. A full-size casting weighed about 100 lbs, and 1 g of HE reportedly is enough to blow off a hand. Kistiakowsky expressed his concerns about using S-Site since five tons of HE had to be trucked past Oppenheimer's office and T-Division every day on its way to S-Site. He requested that a new site be established in Pajarito Canyon, but his request was denied by Captain Parsons (Kistiakowsky, 1975).

L-Site (TA-12, akaTA-67) was constructed in the spring of 1945 and used for one year as an explosives test facility, then abandoned in the mid 1950s. Soil tests in 1993 identified RDX, TNT, and picric acid at the open firing pit and firing pad 1. Q-Site (TA-14) has been used for developing and testing explosives since 1944. HMX and metals were identified in Q-site soils (Harris et al., 1993).

Sites in the vicinity of TA-16 (S-Site) formerly used in the1940s for x-ray studies (P and T-Sites) and assembly operations (V-Site), and several storage magazines (TA-28, 29, and 37) were decommissioned and absorbed into the S-Site complex. S-Site, K-Site and two of the three magazines were still active as of 1994. TA-11 (K-Site) was originally built to study implosion symmetry, and, more recently, was used for drop tests to study explosive impact initiation. The resulting debris in the immediate vicinity of the drop tower is disposed of at the TA-16 burning ground. These eight sites are the focus of the Remedial Field Investigation for Operable Unit 1082 (LANL, 1994).

Between 1944 and 1948, eight firing sites (A-H) were established at TA-15 (R-Site). Experiments using from 50 lbs up to two tons of HE were conducted at these firing points. Firing points E and F were the most active. Up to 65,000 kg of uranium and 350 kg of beryllium were expended at these two firing sites. Hazardous materials, including uranium, beryllium, and lead, have largely been left at these sites where they were deposited by explosions. Other materials that may have been deposited at these sites include

steel, aluminum, mercury, boron, cadmium, gold, and tritium (reportedly in small amounts). TA-15 is the focus of the Remedial Field Investigation for Operable Unit 1086.

Other Uses of Explosives at LANL

During the VJ-Day celebration at LANL, Dr. Kistiakowsky reportedly borrowed a military jeep with a driver and performed a "21-gun salute" by detonating 21 boxes of Comp B explosive, although a celebration party guest reported that there were actually 22 explosions. The Pajarito ski hill was also reportedly cleared of trees using plastic explosives (Kistiakowsky, 1975).

Key Facilities for High Explosives at LANL

S-Site (TA-16) was initially called Sawmill Site, after a portable sawmill that had been erected on the site that had left behind huge piles of sawdust; its name was eventually shortened to just S-Site (Martin, 1998). Activities at S-Site have included nuclear weapon warhead system development, engineering design, prototype manufacture, and environmental testing. TA-16 is also the site of the Weapons Engineering Tritium Facility for tritium handled in glove boxes. High explosive, plastic, and adhesive development and testing, as well as process development research for manufacturing items using these and other materials were accomplished in a number of facilities at the site.

TA-16 facilities included a slurry plant with a capacity of 300 lbs of explosive per batch (Cochran et al., 1987). The cast was made from a two-phased slurry consisting of a dense solid phase dispersed in molten TNT (Hoddeson et al., 1993). Initially Torpex was used, then PTX-2 (Picatinny ternary explosive 2), Comp B, Pentolite, Baranol, and Baratol. Earlier operations centered on using high explosives (HE), and developing HE lenses to bring about implosion. LANL workers melted HE and poured it into molds that were shaped based on theoretical calculations. Early castings were made from a template using hand tools, saws, rasps, and planes. HE compounds used included Comp. B, TNT, and Baratol.

Early explosives processing facilities included:

- S-24 (possibly a.k.a. TA-16-24) A casting building
- TA-16-42 Casting (stainless steel candy kettles, jacketed and steam heated, with agitator; HE was poured into a rubber bucket, then to molds)
- TA-16-43 Machining (K&T milling machine, drill presses, fly cutters. Comp. B was machined under a stream of water. Baratol was initially machined dry because thought water would dissolve the barium nitrate; later machined wet.
- TA-16-44 Physical inspection (dimensional inspection)
- TA-16-45 X-ray (portable 150- and 220-keV x-ray machines. Dark room, film processing.

- TA-16-46 HE storage for X-ray. "Rest House" for castings during dimensional and x-ray inspection.
- TA-16-48 "gamma-graph" facility (gamma radiography of large or dense objects).
- TA-16-55 Barium nitrate grinding machinery.
- TA-16-81 Used to dry nitrocellulose (spread out on trays).
- TA-16-260 Near the east end of this building was an area for daily burning of scrap; sometimes the material exploded instead of burning.
- TA-16-27 Built in 1945 to make full-scale castings.
- 30 thru 34 Built at same time to machine Baratol and Comp. B castings from Building 27.
- 94 thru 98 Built when it became desirable to machine all surfaces of the HE material.
- 16-515 thru 520 (Called V-Site) Were under a group other than GMX-3; they had a large mechanical shaker that was used to test the first bomb. The Trinity bomb was assembled in 516. "Active" per 10/2/84 memo from R. Goldie to D. Pinyan; subject was "Areas Containing or Contaminated by Explosives." "Mechanical Testing" done here per Repository No. 225 (c. 1981)

Some of the early work was considered too dangerous to be performed at TA-1, so these operations were moved to remote locations. Alpha Site at TA-4 was used as a firing site for HE; it was originally used to fire several charges per day of up to 1000 lbs, and was then converted to accommodate studies of small equation-of-state tests that used only a few pounds of HE per shot. Beta Site at TA-5 was used extensively in 1945 as a firing site for the pin or electric method of studying implosions. Larger charges could be safely used at TA-5, and thus shots of several hundred pounds occurred. S-Site at TA-16 was developed to produce HE for use in various tests (LANL, 1997).

In 1944, a small control building and two firing sites were established at TA-15: one for quantities of HE up to 50 lbs, and the second for larger amounts. These sites most likely became Firing Sites A and B; Firing Site A was probably in use by the end of 1944, and Firing Site B shortly thereafter. In 1946, TA-15 was established as a permanent location for explosives experiments related to nuclear weapons design, involving experiments using up to 3/4 tons of HE. By 1947, Firing Sites C, D, E, and F were in use. In 1948, Sites E and F were designated as one firing site, E-F, and Firing Sites G and H were added. Today, Firing Sites A through H are not used, and most structures associated with them have been decommissioned and dismantled. The hazardous materials used in these explosives tests (e.g., U, Be, and Pb) have largely remained at the firing sites where they were either initially deposited by the explosion, or pushed aside to clean the area. Other materials that may have been deposited in very small amounts include steel, Al, Hg, boron, cadmium, gold, and ^{3}H. Many types of HE were used, and while they may have left some residues, no unexploded HE have been found in any site soil analyses. Site E-F was most heavily used, and reportedly contains the largest quantities of hazardous materials. Up to 72 tons of uranium and approximately 800 lbs of beryllium may have been expended in tests at Firing Site E-F. In

the 1950s, Firing Sites R-44 and R-45 were completed; these sites have been used for various explosives tests: R-45 for smaller tests, and R-44 for larger ones (1086 RFI Report; 10/30/95).

TA-15, or R-Site, is currently the home of PHERMEX (the pulsed high-energy radiographic machine emitting x-rays), a multiple-cavity electron accelerator capable of producing a very large flux of x-rays for weapons development testing. It is also the site where DARHT (the dual-axis radiographic hydrotest facility) was constructed. This site is also used for the investigating weapon functioning and systems behavior in non-nuclear tests, principally through electronic recordings.

TA-9, Anchor Site East, housed teams exploring explosive fabrication feasibility and physical properties; new organic compounds were investigated for possible use as explosives. Storage and stability problems were also studied. The site's name referred to Anchor Ranch, a small cattle operation that was in the area when the MED took over in 1943 (Goldie, 1984).

TA-14, or Q Site, is a dynamic testing site used for testing relatively small explosive charges for fragment impacts, explosive sensitivities, and thermal responses (Goldie, 1984).

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Chapter 13: The LANL Health Division

Although LANL's Health Division ("H Division") was responsible for monitoring worker health, operations or activities that were associated with potential worker exposures were often also associated with potential off-site releases and public health consequences. The LAHDRA project team examined a large number of health-related progress reports published by the Health Group, Health Division, and successor organizations that carried out programs related to worker and environmental health. This chapter provides an overview of the organizational structure of the Health Division and its subgroups (such as health physics and industrial hygiene), and describes the various health and safety activities that those groups conducted over the years at LANL. A complete listing of the documents issued by the H Division and it successor groups that the LAHDRA team located and selected as relevant to off-site releases or health effects is presented as an appendix at the end of this chapter.

The project team located and reviewed approximately 430 documents consisting of Health Division Progress Reports or reports from known successors of the Health Division. An example of a successor report might be one named under a different title, such as "Quarterly Progress Report – Group H-1 Health Physics." Many division or group reports were published monthly, although quarterly and annual reports are available for select years, and they were also reviewed. The oldest reports available were the Health Group and Health and Safety reports from 1943 to 1945. In early 1946, Louis H. Hempelmann, M.D., then acting director of the Health Division, wrote a report titled "History of the Health Group (A-6) (March 1943 – November 1945)." That report discusses issues relating to safely handling plutonium and polonium and monitoring and preventing worker exposures to these materials. Discussions of hazards associated with the RaLa and Omega Site operations, as well as other health and safety issues, including injuries, are also presented in the report (Hempelmann, 1946a). Another early Health Group report titled "Health Hazards of LANL Groups by Division," is a compilation of letter-reports that provide summaries of early operational hazards and health and safety measures used by LANL to control worker exposures (Hempelmann, 1946b). Many of the these health groups, such as occupational medicine, industrial hygiene, health and safety, and health physics, remained part of the Health Division through the 1970s.

In 1975, the Health Division expanded its name to "Operational Environmental Health and Safety," and then in 1981 changed it to "Health, Safety, and Environment." The Division has had other name changes since that time, and Divisional activities continue to be published in progress reports under these and other health and safety related division or division group names.

History of H Division

According to the report titled "History of the Health Group," a November 13, 1943 directive from LANL Director J. Robert Oppenheimer stated that the medical supervision of technical personnel was to be directed primarily at protecting workers from the hazards of the project (Hempelmann, 1946). The primary function of the Health Group (A-6) at that time was to establish safe tolerance levels, develop monitoring methods, and to ensure that tolerance levels were not exceeded for worker exposures to hazardous materials. Monitoring and controlling workers' exposures to radioactive materials were of primary concern. Preparing routine monitoring procedures for workers was the primary function of each operational unit or lead individual during this early period. Effluent or environmental monitoring that would be of interest for a dose reconstruction study is not mentioned in this report.

The original policy of the Health Group was to depend entirely on information gained from health research and development groups elsewhere, such as the "Met Lab" in Chicago. The Metallurgical Laboratory or "Met Lab" at the University of Chicago was part of the Manhattan Project. The Met Lab was the organization primarily responsible for Health and Safety during the Manhattan era (Hacker, 1987).

Because that policy and support from outside organizations did not always provide the needed information in time to establish safe operating procedures for use at LANL, research sections were set up within the Health Group, such as for developing instrumentation and biological methods for testing for overexposure (Hempelmann, 1946). Approximately half of the 25- to 30-page monthly reports of the era, for example, describe various areas of research and papers published on the health effects of radiation by H-4, the radiobiology group, and instrument development and testing work conducted by the electronic and biophysics sections of Radiologic Safety, H-1. Accidents were reported in the Occupational Safety group (H-3) section of the division reports.

On June 1, 1947, the Health Group was renamed the Health Division, and Louis H. Hempelmann, M.D. served as Division leader from 1943 until the end of 1948. Thomas L. Shipman, M.D., assumed responsibilities from Hempelmann in 1948. In 1943, the Health Group consisted of 10 staff, which expanded to 97 by 1949; by 1951, the group had grown to 158 staff (Hempelmann, 1946, LASL, 1950b, 1951)

Documentation of H-Division Activities

The Health Group reports were typically called Health Reports, and the Division reports were called H-Division Progress Reports. The Health Reports are organized in three sections: radiation problems, chemical hazards, and general safety. By 1951, the Health Division was divided into six groups.

Monthly progress reports generally consisted of four to seven sections corresponding to the operating groups in the division. The six primary groups that operated under the Health Division included:

- H-1, Administrative and Medical Records; later became Radiologic Safety (later renamed H-1 Health Physics); H-Division administrative activities were reported separately, but not given an H number; Radiologic Safety included monitoring, electronics, and biophysics sections.

- H-2, Occupational Health; included health physics, industrial hygiene, and occupational biochemistry sections; later when Radiologic Safety became a separate group called H-1 Health Physics, Occupational Medical was created to maintain responsibility for general clinical functions such as physicals and first aid.

- H-3, Training of Military personnel and Medical staff (LANL employee care); later became Occupational Safety, and the training function was merged into H-Division Administration.

- H-4, Radiobiology; conducted research on clinical aspects of exposure to chemicals and radionuclides, including monitoring programs and instrumentation.

- H-5, Industrial Hygiene and Occupational Biochemistry sections were split off from H-2 and formed in June 1949.

- H-6, Monitoring (CMR-12); merged into H-1, and then became Radiologic Physics, including the old Biophysics group (Special Problems) and the Meteorology section.

Many of the activities performed by these groups are still being performed today under different divisional and/or group names.

Constructed during 1952-54, the Health Research Laboratory at TA-43 is adjacent to the Los Alamos Medical Center in the Los Alamos town site. Research performed at this site included structural, molecular, and cellular radiobiology, biophysics, mammalian radiobiology, mammalian metabolism, biochemistry, and genetics. The Department of Energy Los Alamos Area Office is also located within TA-43.

The reference list located at the end of this chapter presents the most up to date list of Health Division progress or related group reports that were located and reviewed by the project team. The references are grouped by year and title. These reports document and offer insight into LANL's health and safety program, and describe health protection philosophies used to monitor personnel, work areas, and loss of material to the off-site environment. The list indicates which reports are thought to exist, but have not been located by the project team as of the writing of this report. Some of the missing reports might be

missing because a report was not issued for that period, or copies may have been lost, or perhaps filed differently than other reports of the same type.

Groups within the Health Division or from other divisions with health and safety responsibilities also published monthly or quarterly progress reports. Relevant information pertaining to off-site emissions discovered during document reviews was noted, summarized, and included as appropriate in other sections of this report. Below is a list of H (Health) Division and group reports and the years for which reports were located and reviewed during the LAHDRA project. This list does not necessarily list reports by their exact titles, but rather is intended to provide an overview of the types of health-related reports for various periods. The reference list at the end of this chapter does identify relevant reports by their actual titles.

- Health Reports of the LANL (formerly LASL) Health Division (1943 – 1945)
- Health Division monthly and quarterly progress reports (1946 – 1972)
- Summary of Research, Development, and Health Activities in the CMR Division (1944 – 1951)
- H-1 Monthly Progress/Monitoring Reports DP East and West (1956 – 1966)
- H-1 General Monitoring Section (1956 – 1964)
- Airborne Contamination Tests – CMR TA-1 and TA-3 (1952 – 1973)
- CMR-12 Monthly Reports (1945 – 1950)
- Air Monitoring Results – DP West (1946 – 1952)
- Airborne Contamination Tests – DP West/East (1946 -1970)
- Weekly Reports of Stack Release Data for DP West (1950 – 1956)
- Monthly and Annual Reports, DP East (1951 – 1955)
- Health Physics/Radiation Protection quarterly Reports (1973 – 1991)
- Health, Safety, and Environment quarterly and annual reports (1975 through 1990)
- Environment, Safety, and Health (1990 – 2005)
- Environment, Health, Safety, and Quality (2005 – present)

Health Division Perceptions of Hazards at LANL

In 1943, the hazards of the project were reported to be limited to external radiation from the cyclotron, the Van de Graaff, the D-D source, and the radium sources. There were also hazards attributed to uranium and the usual chemical laboratory hazards, but these were not serious, according to Louis H. Hempelmann. Only one accident was noted as having occurred during the first year of LANL operations; it involved overexposure to radiation from the cyclotron. The main concern of the Health Group at this

time was interpreting blood counts on exposed personnel to radiation. Normal variation in blood counts was not well known at the time (Hempelmann, 1946).

In February, 1944, plutonium arrived at LANL in significant quantities. The members of the Chemistry and Metallurgy (CM) Division and the Health Group became concerned about the dangers of working with this material. Control of alpha-emitting radioactive materials was described as rather uneventful for the first year. After an accident in August, 1944 in which a milligram of plutonium blew up in a worker's face, a research program to develop tests for detecting overexposure of personnel with plutonium began. A urine test was developed in January, 1945 that required a new (free of alpha contamination) laboratory (ML Building) to conduct the bioassay tests. Following the first human tracer experiment in April, 1945, results of the urine tests were evaluated with increased certainty. Until the urine test was perfected, nose counts were the only index used to monitor personnel exposures. Because of the difficult and time consuming nature of the urine test, the most heavily exposed persons as indicated by nose counts underwent frequent urinalyses. Available alpha monitoring equipment lacked both sensitivity and portability, so swipe samples were used to detect contaminated hands, nostrils, and workplaces. A proportional counter using a methane-filled, thin windowed tube was developed by D. Froman and R. Watts at LANL, and installed in the D-Building washroom as a hand counter in June, 1944 (Hempelmann, 1946).

In September, 1944, the CM-1 group was reorganized, and many members of the monitoring and decontamination section were transferred to A-6, the Health Group. The new structure did not lead to cooperation between the two groups, and in January, 1945, H-1 (CM-12), was given full responsibility for the entire alpha contamination problem in the CM Division. At that time it was necessary to redesign the existing facilities in D-Building in order to safely handle the increased amounts of plutonium being used there. In July, 1945, CM-5 handled amounts of plutonium that exceeded the capacity of its safety equipment, and four workers exceeded the safe amount of one microgram of plutonium in their bodies, according to urine tests.

According to Louis Hempelmann, polonium was significantly less of a hazard than plutonium. Because it was less radioactive, easier to test in the urine, and most often used in relatively simple technical operations, polonium contamination and exposure hazards were minimal. By 1946, only two workers had exceeded the tolerance limit for polonium (1500 counts per minute, "cpm," in a 24-h urine sample) (Hempelmann, 1946).

The perceived external radiation hazard at LANL did not change until September, 1944, when the Water Boiler reactor at Omega Site went into operation. Later, when a higher powered version replaced it (January, 1945), there were several instances of overexposure when the exhaust line developed leaks.

There was also an accident that resulted in serious exposure to several chemists during decontamination of active material. By the time of Hempelmann's 1946 early history summary, there had been two serious accidents in critical assembly work at Omega Site: one that overexposed four individuals to gamma and neutron radiation, and one fatality. The report does discuss concerns for off-site emissions, monitoring, and control measures (Hempelmann, 1946).

During the radioactive lanthanum (RaLa) implosion tests that started in September, 1944, members of the chemistry group CM-4 received periodic overexposures to beta radiation. The toxicity and accepted methods for preventing toxicity from exposure to high explosives were more familiar. In certain cases, safe operational procedures were delayed because of construction inadequacies in the exhaust systems, washrooms, etc., but no serious trouble was encountered between March, 1943 and October, 1945, according to some H-Division reports (Hempelmann, 1946).

Although monthly H-Division reports from 1947-onward repeatedly mention beryllium hazards, there is no mention of beryllium in Hempelmann (1946b). Table 13-1 presents a summary of materials of concern in terms of potential health hazard, based on review of H-Division reports.

Table 13-1. Materials of concern from H-Division reports

Material of Concern (Location of Concern)	**Examples of H-Division Reports (LAHDRA Project Repos. Number)**
Arsine	2275, 2392
Benzol (DP West)	2259, 2266, 2267
Beryllium (V Shop, Sigma, R-Site, CMR)	2202, 2433, 2434, 2258, 2259, 2262, 2300, 2224, 2392
Fluorides (D-Building)	2266
Lithium (Sigma, K)	2270, 2275, 2300, 2301, 2298
Mercury spills (Omega Site, U-14, K bldg)	2433, 2434, 2211, 2259, 2298
Polynuclear Aromatic Hydocarbons (scintillation fluids)	2209, 2270, 2275, 2216
Impurities in RaLa source (Bayo)	2207, 2261, 2262, 2263, 2267, 2268, 2301
Trichloroethylene (TU, Sandia, Omega, S-Site)	2259, 2260, 2265, 2267, 2201
TNT (S-Site)	2257, 2433, 2434, 2258, 2260, 2264, 2201
Thorium	2287, 2383
Uranium (TU, Sigma, HT)	2257, 2211, 2263, 2216, 2224
Plutonium	2330, 2375, 7188
Polonium	124, 3049, 7188

Incidents Documented in H-Division Reports

Following are examples of the type of information contained in the monthly H-Division reports. These examples come from reports covering a time period from approximately the mid-1950s to the mid-1960s,

and highlight operational conditions at LANL and effluent monitoring activities are relevant to the LAHDRA project.

Examples of chronic issues or problems cited include:

- Liquid waste management problems at Ten Site (TA-35) for the liquid waste streams generated by the RaLa program. Problems with plant capacity and equipment lead to several unplanned discharges of large volumes of radiostrontium-bearing wastes to Mortandad Canyon.
- Leakage around improperly installed filtration units site-wide. For example, a report issued on the release of alpha activity from DP West stacks in 1955 states "definitely that the CWS-6 filters are poorly installed and consistently leak contaminated air around the edges of the filters" (Shipman, 1955). In 1964, in-place DOP-testing of the filters on top of DP West Building 4 showed their efficiency to be "approximately 15%" (LASL, 1964).
- Glove box explosions and fires at DP West Site are reported in numerous reports.
- Emissions of TNT dust from facilities at S-Site (TA-16) are reported in numerous reports.
- Beryllium contamination of soil at R-site (TA-15). The magnitude of the contamination and the potential for resuspension prompted remediation activities on several occasions.
- Unsatisfactory media and methods for sampling airborne effluent streams for radioactive iodine due to low and unpredictable collection efficiencies. This problem was a particular issue for quantifying radioiodine releases from Wing 9 of the CMR Building, but it was also seen at Omega Site and DP West Site.
- Lack of suitable instrumentation and methods for monitoring airborne effluents from the Omega Stack, and corresponding uncertainty in assessments of exposure to residents of the old trailer court area (most likely the trailer park on DP Road and overlooking Omega Site; see Chapter 15).
- Lack of appropriate monitoring instrumentation was also a chronic issue at Ten Site, where stack effluents during RaLa source preparation activities often could not be assayed because of excessive radioactivity.
- Containment mechanism failures for samples being irradiated in the Omega West Reactor. For example, such a failure on August 7, 1961 resulted in contamination of cars in the parking lot and in other areas around the building (LASL, 1961b). On December 23, 1963, a rather large "sample" was irradiated in the reactor's vertical port and had to be removed through the roof of the building. The sample was then dragged down the road to its storage location. Afterward, the

roof of the building and the road read 50 mR h^{-1} and 20 mR h^{-1}, respectively, from contamination by ^{122}Sb and ^{124}Sb (Shipman, 1964).

- Soil and groundwater contamination downstream from the TA-35, TA-45, and (in later years) TA-50 liquid waste outfalls were reported during the 1950s and 1960s in various reports

Specific examples of contamination being spread to private property include:

- A contamination incident at the Water Boiler on August 16, 1950 resulted in contamination being spread to a private home (LASL, 1950a).
- In 1961, a ^{137}Cs contamination incident at TA-48 resulted in contamination being tracked off site by workers; 28 homes and 47 vehicles were surveyed for contamination (LASL, 1961a).
- ^{90}Sr contamination was spread to a worker's vehicle on June 2, 1961 from a spill at the H-7 waste treatment laboratory (LASL, 1961c).

Specific examples of episodic events and sources of fugitive and unmonitored emissions include:

- On January 8, 1953, LANL discovered that a polonium-beryllium source had ruptured at the Pajarito Site, and found that contamination had spread to Los Alamos residential areas. Follow-up monitoring was performed to assess the extent of the unmonitored release (Shipman, 1953).
- Dust from the demolition of contaminated buildings in TA-1. Demolition activities included Buildings CM, D, HT, J-2, M, ML, and N. Debris from these demolition projects was often burned at the contaminated dump site.
- In 1956, glass vials containing tritium gas were disposed of at Beta Site (TA-5) by placing ten at a time in a barrel and dropping a weight on them. At one point, a tritium concentration of 15,000 $\mu Ci\ m^{-3}$ was measured at a distance of 100 ft from the barrel.
- Unintentional releases of tritium from Building TA-33-86 required the site to be evacuated and access restricted by road blocks on multiple occasions (Shipman, 1958, 1959b).
- A nuclear criticality accident at DP West (Building 2) on December 30, 1958 killed one worker and exposed numerous others (Shipman, 1959a).
- A fire in a plutonium-contaminated CWS filter at DP West Room 501 on July 15, 1959. Highly-contaminated ash was found both inside and outside the building (Shipman, 1959b). Another fire occurred in the incinerator drybox exhaust system in DP West Room 313 on December 8, 1959. Buildup of residues allowed the fire to spread throughout the exhaust system. The exhaust stack reportedly was red hot up to five feet above the roof (LASL, 1959).

- In 1960, hydrogen sulfide emissions from Building TA-46-1 led to complaints from workers about fumes being drawn back into the building through the intake air system (Shipman, 1960).

References

Hacker BC. The dragon's tail - radiation safety in the Manhattan project 1942-46. Berkeley: Univ. of California Press; 1987.

Hempelmann LH. History of the Health Group (A-6) March 1943 - November 1945; from LANL Records Center location E-11-117, TR11921 Los Alamos Scientific Laboratory. 1946.

Hempelmann LH. History of the Health Group (A-6) March 1943 - November 1945. from LANL Records Center location E-11-117, TR11921 Los Alamos Scientific Laboratory; 1946a.

Hempelmann LH. Health hazards of LASL groups. from LANL Records Center location E-13-25, TR6704, Folder 11 Los Alamos Scientific Laboratory; 1946b.

LASL. H-Division Progress Report, July 20, 1950 - August 20, 1950. Los Alamos, NM: Los Alamos Scientific Laboratory; 1950a.

LASL. H Division Annual Report 1949. Los Alamos, NM: Los Alamos Scientific Laboratory; LA-1072; 1950b.

LASL. H-Division Annual Report, 1950. Los Alamos, NM: Los Alamos Scientific Laboratory; 1951.

LASL. H-Division Progress Report, November 20, 1959 - December 20, 1959. Los Alamos, NM: Los Alamos Scientific Laboratory; 1959.

LASL. H Division Monthly Progress Report, April 20, 1961 - May 20, 1961. Los Alamos, NM: Los Alamos Scientific Laboratory; 1961a.

LASL. H Division Monthly Progress Report, July 20, 1961 - August 20, 1961. Los Alamos, NM: Los Alamos Scientific Laboratory; 1961b.

LASL. H Division Monthly Progress Report, May 20, 1961 - June 20, 1961 Los Alamos, NM: Los Alamos Scientific Laboratory; 1961c.

LASL. H-Division Progress Report, July 21, 1964 - August 20, 1964. Los Alamos, NM: Los Alamos Scientific Laboratory; 1964.

Shipman TL. H Division Monthly Progress Report, December 20, 1952 - January 20, 1953. Los Alamos, NM: Los Alamos National Laboratory; 1953.

Shipman TL. H Division Monthly Progress Report, H-219, September 20, 1955 - October 20, 1955. Los Alamos, NM: Los Alamos National Laboratory; 1955.

Shipman TL. H Division Monthly Progress Report, H-279, July 20, 1958 - August 20, 1958. Los Alamos, NM: Los Alamos National Laboratory; 1958.

Shipman TL. H Division Monthly Progress Report, H-285, December 20, 1958 - January 20, 1959. Los Alamos, NM: Los Alamos National Laboratory; 1959a.

Shipman TL. H Division Monthly Progress Report, May 20, 1959 - June 20, 1959. Los Alamos, NM: Los Alamos National Laboratory; 1959b.

Shipman TL. H Division Monthly Progress Report, H-299, August 20, 1960 - September 20, 1960. Los Alamos, NM: Los Alamos National Laboratory; 1960.

Shipman TL. H Division Monthly Progress Report, December 21, 1963 - January 20, 1964. Los Alamos, NM: Los Alamos Scientific Laboratory; 1964.

Appendix 13A: Listing of Reports Issued by the Los Alamos Health Group, Health Division, and Successor Groups

The following compilation of reference documents related to LANL's Health Division highlights those sources of information that contain information relevant to operational activities and effluent monitoring practices, particularly for those early operational years when reporting of source term information (i.e., basic monitoring data, sampling methods) varied in content both in quantity and quality and are presented in a variety of division and group report formats. The reference list is organized chronologically and grouped by report titles.

1943 – 1946 Health Group Reports

Hempelmann, L. H. 1943a – Health Report, LAMS-6, August 9, 1943 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7184

Hempelmann, L. H. 1943b – Health Report, LAMS-10, September 23, 1943 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7185

Hempelmann, L. H. 1943c – Health Report, LAMS-23, November 4, 1943 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7186

Hempelmann, L. H. 1943d – Health Report, LAMS-32, December 9, 1943 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7187

Hempelmann, L. H. 1944a – Health Report, LAMS-46, January 19 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2963

Hempelmann, L. H. 1944b – Health Report, LAMS-67, February 25, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2692

Hempelmann, L. H. 1944c – Health Report, LAMS-81, April 14, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7188

Hempelmann, L. H. 1944d – Health Report, LAMS-103, May 31, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7191

Hempelmann, L. H. 1944e – Health Report, LAMS-126, August 30, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 3953

Hempelmann, L. H. 1944f – Health Report, LAMS-157, Month Ending September 30, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2257

Hempelmann, L. H., 1946a, History of the Health Group (A-6), March 1943 – November 1945, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. April 6, 1945. Repos. No. 978

Hempelmann, L. H., 1946b, Health Hazards of LANL Groups by Division, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 136

1944 – 1945 Health and Safety Reports

LASL (Los Alamos Scientific Laboratory), 1944a, Health and Safety Report – CM Division LAMS-87, April, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7189

LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-99, May, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7190

LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-108, June, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7192

LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-129, August, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7193

LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-143, September, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7194

Steinhardt, R.G., 1945, Summary Report on Health Conditions in RaLa Program, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6774

1947 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1947a, H Division Monthly Progress Report, LAMS-595, May 20, 1947 - July 20, 1947, HSPT-REL-94-275, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2202

LASL (Los Alamos Scientific Laboratory), 1947b, H Division Monthly Progress Report, LAMS-610, July 20, 1947 - August 20, 1947, HSPT-REL-94-310, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2272

LASL (Los Alamos Scientific Laboratory), 1947c, H Division Monthly Progress Report, LAMS-623, August 20, 1947 - September 20, 1947, HSPT-REL-94-311, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2273

LASL (Los Alamos Scientific Laboratory), 1947d, H Division Monthly Progress Report, LAMS-644, September 20, 1947 - October 20, 1947, HSPT-REL-94-312, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2274

LASL (Los Alamos Scientific Laboratory), 1947e, H Division Monthly Progress Report, LAMS-651, October 20, 1947 - November 20, 1947, HSPT-REL-94-277, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2204

LASL (Los Alamos Scientific Laboratory), 1947f, H Division Monthly Progress Report, LAMS-671, November 20, 1947 - December 20, 1947, HSPT-REL-94-278, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2205

LASL (Los Alamos Scientific Laboratory), 1947g, H Division Annual Report 1947, November 24, 1947, HSPT-REL-94-276, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2203

1948 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1948a, H Division Monthly Progress Report, LAMS-687, January 1, 1948 - February 5, 1948, HSPT-REL-94-279, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2206

LASL (Los Alamos Scientific Laboratory), 1948b, H Division Monthly Progress Report, LAMS-700, January 21, 1948 - February 20, 1948, HSPT-REL-94-280, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2207

LASL (Los Alamos Scientific Laboratory), 1948c, H Division Monthly Progress Report, LAMS-716, February 20, 1948 - March 20, 1948, HSPT-REL-94-281, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2208

LASL (Los Alamos Scientific Laboratory), 1948d, H Division Monthly Progress Report, LAMS-726, March 21, 1948 - April 20, 1948, HSPT-REL-94-282, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2209

LASL (Los Alamos Scientific Laboratory), 1948e, H Division Monthly Progress Report, LAMS-741, April 20, 1948 - May 20, 1948, HSPT-REL-94-283, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2210

Note: H Division Monthly Progress Reports for May 20 – June 20, 1948 and June 20 – July 20, 1948 have not been located at LANL.

LASL (Los Alamos Scientific Laboratory), 1948f, H Division Monthly Progress Report, LAMS-783, July 20, 1948 - August 20, 1948, HSPT-REL-94-253, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2258

LASL (Los Alamos Scientific Laboratory), 1948fg H Division Monthly Progress Report, LAMS-790, August 20, 1948 - September 20, 1948, HSPT-REL-94-254, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2259

LASL (Los Alamos Scientific Laboratory), 1948h, H Division Monthly Progress Report, LAMS-803, September 20, 1948 - October 20, 1948, HSPT-REL-94-257, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2260

LASL (Los Alamos Scientific Laboratory), 1948i, H Division Monthly Progress Report, October 20, 1948 - November 20, 1948, HSPT-REL-94-258, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2261

LASL (Los Alamos Scientific Laboratory), 1948j, H Division Monthly Progress Report, LAMS 828, November 20, 1948 - December 20, 1948, HSPT-REL-94-259, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2262

Note: An H Division Annual Progress Report for 1948 has not been located at LANL.

1949 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1949a, H Division Monthly Progress Report, LAMS 846, December 20, 1948 - January 20, 1949 HSPT-REL-94-285, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2211

LASL (Los Alamos Scientific Laboratory), 1949b, H Division Monthly Progress Report, LAMS 805, January 20, 1949 - February 20, 1949, HSPT-REL-94-302, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2266

LASL (Los Alamos Scientific Laboratory), 1949c, H Division Monthly Progress Report, LAMS 877, February 20, 1949 - March 20 1949, HSPT-REL-94-301, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2265

LASL (Los Alamos Scientific Laboratory), 1949d, H Division Monthly Progress Report, LAMS 889, March 20, 1949 - April 20, 1949, HSPT-REL-94-260, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2263

LASL (Los Alamos Scientific Laboratory), 1949e, H Division Monthly Progress Report, LAMS 901, April 20, 1949 - May 20, 1949, HSPT-REL-94-262, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2264

LASL (Los Alamos Scientific Laboratory), 1949f, H Division Monthly Progress Report, LAMS 917, May 20, 1949 - June 20, 1949, HSPT-REL-94-264, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2300

LASL (Los Alamos Scientific Laboratory), 1949g, H Division Monthly Progress Report, LAMS 929, June 20, 1949 - July 20, 1949, HSPT-REL-94-266, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2301

LASL (Los Alamos Scientific Laboratory), 1949h, H Division Monthly Progress Report, LAMS 941, July 20, 1949 - August 20, 1949, HSPT-REL-94-304, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2267

LASL (Los Alamos Scientific Laboratory), 1949i, H Division Monthly Progress Report, LAMS 956, August 20, 1949 - September 20, 1949, HSPT-REL-94-306, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2268

Note: An H Division Monthly Progress Report for September 20 – October 20, 1949 was not located at LANL.

LASL (Los Alamos Scientific Laboratory), 1949j, H Division Monthly Progress Report, October 20, 1949 - November 20, 1949, HSPT-REL-94-307, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2271

LASL (Los Alamos Scientific Laboratory), 1949k, Abstract - H Division Monthly Progress Report, November 20, 1949 - December 20, 1949, HSPT-REL-94-308, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2269

Note: An H Division Monthly Progress Report for November 20, 1949 - December 20, 1949 was not located during project research activities

LASL (Los Alamos Scientific Laboratory), 1950a, H Division Annual Report 1949, LA-1072, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2270

1950 Health Division Reports

Note: An H Division Monthly Progress Report for December 20, 1949 - January 20, 1950 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1950b, H Division Monthly Progress Report, January 20, 1950 - February 20, 1950, HSPT-REL-94-302, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2212

LASL (Los Alamos Scientific Laboratory), 1950c, Abstract, H Division Monthly Progress Report, February 20, 1950 - March 20, 1950, HSPT-REL-94-287, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2213

LASL (Los Alamos Scientific Laboratory), 1950d, Abstract, H Division Monthly Progress Report, March 20, 1950 - April 20, 1950, HSPT-REL-94-288, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2214

LASL (Los Alamos Scientific Laboratory), 1950e, Abstract, H Division Monthly Progress Report, April 20, 1950 - May 20, 1950, HSPT-REL-94-289, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2215

LASL (Los Alamos Scientific Laboratory), 1950f, H Division Monthly Progress Report, May 20 - June 20, 1950, HSPT-REL-94-290, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2216

LASL (Los Alamos Scientific Laboratory), 1950g, H Division Monthly Progress Report, June 20, 1950 - July 20, 1950, HSPT-REL-94-292, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2218

LASL (Los Alamos Scientific Laboratory), 1950h, H Division Monthly Progress Report, July 20, 1950 - August 20, 1950, HSPT-REL-94-294, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2219

LASL (Los Alamos Scientific Laboratory), 1950i, H Division Monthly Progress Report, August 20, 1950 - September 20, 1950, HSPT-REL-94-296, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2220

LASL (Los Alamos Scientific Laboratory), 1950j, H Division Monthly Progress Report, September 20, 1950 - October 20, 1950, HSPT-REL-94-267, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2302

LASL (Los Alamos Scientific Laboratory), 1950k, H Division Monthly Progress Report, October 20, 1950 - November 20, 1950, HSPT-REL-94-270, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2304

Note: An H Division Monthly progress report for November 20 - December 20, 1950 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1951a, H Division Annual Report 1950, HSPT-REL-94-354, LA-1256, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2224

1951 Health Division Reports

Note: An H Division Monthly Progress Report for December 20, 1950 - January 20, 1951 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1951b, H Division Monthly Progress Report, January 20, 1951 - February 20, 1951, HSPT-REL-94-274, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2201

LASL (Los Alamos Scientific Laboratory), 1951c, H Division Monthly Progress Report, February 20, 1951 - March 20, 1951, HSPT-REL-94-298, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2221

LASL (Los Alamos Scientific Laboratory), 1951d, H Division Monthly Progress Report, March 20, 1951 - April 20, 1951, HSPT-REL-94-300, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2223

LASL (Los Alamos Scientific Laboratory), 195e1, H Division Monthly Progress Report, April 20, 1951 - May 20, 1951, HSPT-REL-94-355, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2225

LASL (Los Alamos Scientific Laboratory), 1951f, H Division Monthly Progress Report, May 20, 1951 - June 20, 1951, HSPT-REL-94-357, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2226

LASL (Los Alamos Scientific Laboratory), 1951g, H Division Monthly Progress Report, June 20, 1951 - July 20, 1951, HSPT-REL-94-360, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2227

LASL (Los Alamos Scientific Laboratory), 1951h, H Division Monthly Progress Report, July 20, 1951 - August 20, 1951, HSPT-REL-94-362, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2228

Shipman, T. L., 1951a, H Division Monthly Progress Report, August 20, 1951 - September 20, 1951, HSPT-REL-94-326, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2282

Shipman, T. L., 1951b, H Division Monthly Progress Report, September 20, 1951 - October 20, 1951, HSPT-REL-94-327, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2283

Shipman, T. L., 1951c, H Division Monthly Progress Report, October 20, 1951 - November 20, 1951, HSPT-REL-94-329, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2284

Shipman, T. L., 1951d, H Division Monthly Progress Report, November 20, 1951 - December 20, 1951, HSPT-REL-94-330, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2285

Shipman, T. L., 1952a, H Division Annual Report 1951 HSPT-REL-94-334, LA-1425, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2287

1952 Health Division Reports

Shipman, T. L., 1952b, H Division Monthly Progress Report, December, 20, 1951 - January 20, 1952, HSPT-REL-94-335, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2288

Shipman, T. L., 1952c, H Division Monthly Progress Report, January 20, 1952 - February 20, 1952, HSPT-REL-94-337, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2289

Shipman, T. L., 1952d, H Division Monthly Progress Report, February 20, 1952 - March 20, 1952, HSPT-REL-94-338, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2290

Shipman, T. L., 1952e, H Division Monthly Progress Report, March 20, 1952 - April 20, 1952, HSPT-REL-94-340, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2291

Shipman, T. L., 1952f, H Division Monthly Progress Report, April 20, 1952 - May 20, 1952, HSPT-REL-94-341, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2292

Shipman, T. L., 1952g, H Division Monthly Progress Report, May 20, 1952 - June 20, 1952, HSPT-REL-94-344, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2293

Shipman, T. L., 1952h, H Division Monthly Progress Report, June 20, 1952 - July 20, 1952, HSPT-REL-94-346, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2294

Shipman, T. L., 1952i, H Division Monthly Progress Report, July 20, 1952 - August 20, 1952, HSPT-REL-94-347, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2295

Shipman, T. L., 1952j, H Division Monthly Progress Report, August 20, 1952 - September 20, 1952, HSPT-REL-94-349, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2296

Shipman, T. L., 1952k, H Division Monthly Progress Report, September 20, 1952 - October 20, 1952, HSPT-REL-94-350, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2297

Shipman, T. L., 1952l, H Division Monthly Progress Report, October 20, 1952 - November 20, 1952, HSPT-REL-94-351, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2298

Shipman, T. L., 1952m, H Division Monthly Progress Report, November 20, 1952 - December 20, 1952, HSPT-REL-94-353, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2299

Shipman, T. L., 1953a, H Division Annual Report 1952, HSPT-REL-94-313, LA-1538, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2275

1953 Health Division Reports

Shipman, T. L., 1953b, H Division Monthly Progress Report, December 20, 1952 - January 20, 1953, HSPT-REL-94-316, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2276

Shipman, T. L., 1953c, H Division Monthly Progress Report, January 20, 1953 - February 20, 1953, HSPT-REL-94-318, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2278

Shipman, T. L., 1953d, H Division Monthly Progress Report, February 20, 1953 - March 20, 1953, HSPT-REL-94-320, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2279

LASL (Los Alamos Scientific Laboratory), 1953a, H Division Monthly Progress Report, March 20, 1953 - April 20, 1953, HSPT-REL-94-322, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2280

Shipman, T. L., 1953e, H Division Monthly Progress Report, April 20, 1953 - May 20, 1953, HSPT-REL-94-325, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2281

Shipman, T. L., 1953f, H Division Monthly Progress Report, May 20, 1953 - June 20, 1953, HSPT-REL-94-397, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2327

Shipman, T. L., 1953g, H Division Monthly Progress Report, June 20, 1953 - July 20, 1953, HSPT-REL-94-398, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2328

Shipman, T. L., 1953h, H Division Monthly Progress Report, July 20, 1953 - August 20, 1953, HSPT-REL-94-399, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2336

Shipman, T. L., 1953i, H Division Monthly Progress Report, August 20, 1953 - September 20, 1953, HSPT-REL-94-400, H-94A, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2337

Shipman, T. L., 1953j, H Division Monthly Progress Report, September 20, 1953 - October 20, 1953, HSPT-REL-94-401, H-95, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2335

Shipman, T. L., 1953k, H Division Monthly Progress Report, October 20, 1953 - November 20, 1953, HSPT-REL-94-403, H-96 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2334

Shipman, T. L., 1953l, H Division Monthly Progress Report, November 20, 1953 - December 20, 1953, HSPT-REL-94-404, H-99, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2333

Shipman, T. L., 1954a, H Division Annual Report 1953, HSPT-REL-94-406, LA-1689, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2330

1954 Health Division Reports

Shipman, T. L., 1954b, H Division Monthly Progress Report, H-102, December 20, 1953 - January 20, 1954, HSPT-REL-94-405, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2326

Shipman, T. L., 1954c, H Division Monthly Progress Report, H-110, January 20, 1954 - February 20, 1954, HSPT-REL-94-407, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2331

Shipman, T. L., 1954d, H Division Monthly Progress Report, H-113, February 20, 1954 - March 20, 1954, HSPT-REL-94-408, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2332

Shipman, T. L., 1954e, H Division Monthly Progress Report, H-117, March 20, 1954 - April 20, 1954, HSPT-REL-94-409, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2361

Shipman, T. L., 1954f, H Division Monthly Progress Report, H-119, April 20, 1954 - May 20, 1954, HSPT-REL-94-410, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2362

Shipman, T. L., 1954g, H Division Monthly Progress Report, H-120, May 20, 1954 - June 20, 1954, HSPT-REL-94-412, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2363

Shipman, T. L., 1954h, H Division Monthly Progress Report, H-122, June 20, 1954 - July 20, 1954, HSPT-REL-94-413, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2364

Shipman, T. L., 1954i, H Division Monthly Progress Report, H-200, July 20, 1954 - August 20, 1954, HSPT-REL-94-457, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2365

Shipman, T. L., 1954j, H Division Monthly Progress Report, H-201, August 20, 1954 - September 20, 1954, HSPT-REL-94-458, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2366

Shipman, T. L., 1954k, H Division Monthly Progress Report, H-202, September 20, 1954 - October 20, 1954, HSPT-REL-94-459, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2367

Shipman, T. L., 1954l, H Division Monthly Progress Report, H-204, October 20, 1954 - November 20, 1954, HSPT-REL-94-460, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2368

Shipman, T. L., 1954m, H Division Monthly Progress Report, H-206, November 20, 1954 - December 20, 1954, HSPT-REL-94-461, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2369

Shipman, T. L., 1955a, Annual Report of the Health Division 1954, LA-1888, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 3053

1955 Health Division Reports

Shipman, T. L., 1955b, H Division Monthly Progress Report, H-207, December 20, 1954 - January 20, 1955, HSPT-REL-94-462, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2370

Shipman, T. L., 1955c, H Division Monthly Progress Report, H-208, January 20, 1955 - February 20, 1955, HSPT-REL-94-464, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2371

Shipman, T. L., 1955d, H Division Monthly Progress Report, H-209, February 20, 1955 - March 20, 1955, HSPT-REL-94-465, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2372

Shipman, T. L., 1955e, H Division Monthly Progress Report, H-210, March 20, 1955 - April 20, 1955, HSPT-REL-94-466, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2373

Shipman, T. L., 1955f, H Division Monthly Progress Report, H-212, April 20, 1955 - May 20, 1955, HSPT-REL-94-467, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2374

Shipman, T. L., 1955g, H Division Monthly Progress Report, H-214, May 20, 1955 - June 20, 1955, HSPT-REL-94-415, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2375

Shipman, T. L., 1955h, H Division Monthly Progress Report, H-215, June 20, 1955 - July 20, 1955, HSPT-REL-94-417, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2376

Shipman, T. L., 1955i, H Division Monthly Progress Report, H-216, July 20, 1955 - August 20, 1955, HSPT-REL-94-888, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2377

Shipman, T. L., 1955j, H Division Monthly Progress Report, H-218, August 20, 1955 - September 20, 1955, HSPT-REL-94-889, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2378

Shipman, T. L., 1955k, H Division Monthly Progress Report, H-219, September 20, 1955 - October 20, 1955, HSPT-REL-94-890, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2379

Shipman, T. L., 1955l, H Division Monthly Progress Report, H-220, October 20, 1955 - November 20, 1955, HSPT-REL-94-891, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2380

Shipman, T. L., 1955m, H Division Monthly Progress Report, H-223, November 20, 1955 - December 20, 1955, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4943

Note: An H Division Annual Progress Report for 1955 was not located during project research activities.

1956 Health Division Reports

Shipman, T. L., 1956a, H Division Monthly Progress Report, H-225, December 20, 1955 - January 20, 1956, HSPT-REL-94-892, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2381

Shipman, T. L., 1956b, H Division Monthly Progress Report, H-277, January 20, 1956 - February 20, 1956, HSPT-REL-94-512, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2382

Shipman, T. L., 1956c, H Division Monthly Progress Report, H-228, February 20, 1956 - March 20, 1956, HSPT-REL-94-513, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2383

Shipman, T. L., 1956d, H Division Monthly Progress Report, H-230, March 20, 1956 - April 20, 1956, HSPT-REL-94-514, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2384

Shipman, T. L., 1956e, H Division Monthly Progress Report, H-236, April 20, 1956 - May 20, 1956, HSPT-REL-94-515, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2385

Shipman, T. L., 1956f, H Division Monthly Progress Report, H-238, May 20, 1956 - June 20, 1956, HSPT-REL-94-517, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2386

Shipman, T. L., 1956g, H Division Monthly Progress Report, H-239, June 20, 1956 - July 20, 1956, HSPT-REL-94-518, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2387

Note: An H Division Monthly Progress Report for July 20 – August 20, 1956 was not located during project research activities.

Shipman, T. L., 1956h, H Division Monthly Progress Report, H-241, August 20, 1956 - September 20, 1956, HSPT-REL-94-519, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2388

Shipman, T. L., 1956i, H Division Monthly Progress Report, H-242, September 20, 1956 - October 20, 1956, HSPT-REL-94-520, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2389

Shipman, T. L., 1956j, H Division Monthly Progress Report, H-246, October 20, 1956 - November 20, 1956, HSPT-REL-94-521, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2390

Shipman, T. L., 1956k, H Division Monthly Progress Report, H-249, November 20, 1956 - December 20, 1956, HSPT-REL-94-445, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2391

Note: An H Division Annual Progress Report for 1956 was not located during project research activities.

1957 Health Division Reports

Shipman, T. L., 1957a, H Division Monthly Progress Report, H-250, December 20, 1956 - January 20, 1957, HSPT-REL-94-446, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2488

Shipman, T. L., 1957b, H Division Monthly Progress Report, H-255, January 20, 1957 - February 20, 1957, HSPT-REL-94-447, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2393

Shipman, T. L., 1957c, H Division Monthly Progress Report, H-258, February 20, 1957 - March 20, 1957, HSPT-REL-94-893, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2394

Note: An H Division Monthly Progress Report for March 20 - April 20, 1957 was not located during project research activities.

Shipman, T. L., 1957d, H Division Monthly Progress Report, H-262, April 20, 1957 - May 20, 1957, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4944

Shipman, T. L., 1957e, H Division Monthly Progress Report, H-262, May 20, 1957 - June 20, 1957, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4945

Shipman, T. L., 1957f, H Division Monthly Progress Report, June 20, 1957 - July 20, 1957, HSPT-REL-94-895; H-265, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2411

Shipman, T. L., 1957g, H Division Monthly Progress Report, H-266, July 20, 1957 - August 20, 1957, HSPT-REL-94-896, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2412

Shipman, T. L., 1957h, H Division Monthly Progress Report, H-267, August 20, 1957 - September 20, 1957, HSPT-REL-94-897, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2413

Shipman, T. L., 1957i, H Division Monthly Progress Report, H-268, September 20, 1957 - October 20, 1957, HSPT-REL-94-898, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2414

Shipman, T. L., 1957j, H Division Monthly Progress Report, H-270, October 20, 1957 - November 20, 1957, HSPT-REL-94-449, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2489

Shipman, T. L., 1957k, H Division Monthly Progress Report, H-271, November 20, 1957 - December 20, 1957, HSPT-REL-94-450, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2490

Shipman, T. L., 1958a, Annual Report, Health Division 1957, HSPT-REL-94-451, LA-,2216 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2392

1958 Health Division Reports

Shipman, T. L., 1958b, H Division Monthly Progress Report, H-272, December 20, 1957 - January 20, 1958, HSPT-REL-94-899, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2415

Shipman, T. L., 1958c, H Division Monthly Progress Report, H-273, January 20, 1958 - February 20, 1958, HSPT-REL-94-900, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2416

Shipman, T. L., 1958d, H Division Monthly Progress Report, H-274, February 20, 1958 - March 20, 1958, HSPT-REL-94-901, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2417

Shipman, T. L., 1958e, H Division Monthly Progress Report, H-275, March 20, 1958 - April 20, 1958, HSPT-REL-94-902, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2418

Shipman, T. L., 1958f, H Division Monthly Progress Report, H-276, April 20, 1958 - May 20, 1958, HSPT-REL-94-903, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2419

Shipman, T. L., 1958g, H Division Monthly Progress Report, H-277, May 20, 1958 - June 20, 1958, HSPT-REL-94-904, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2420

Shipman, T. L., 1958h, H Division Monthly Progress Report, H-278, June 20, 1958 - July 20, 1958, HSPT-REL-94-905, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2421

Shipman, T. L., 1958i, H Division Monthly Progress Report, H-279, July 20, 1958 - August 20, 1958, HSPT-REL-94-906, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2422

Shipman, T. L., 1958j, H Division Monthly Progress Report, H-282, August 20, 1958 - September 20, 1958, HSPT-REL-94-907, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2423

Shipman, T. L., 1958k, H Division Monthly Progress Report, H-283, September 20, 1958 - October 20, 1958, HSPT-REL-94-523, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2509

Shipman, T. L., 1958l, H Division Monthly Progress Report, H-284, October 20, 1958 - November 20, 1958, HSPT-REL-94-525, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2510

Shipman, T. L., 1958m, H Division Monthly Progress Report, November 20, 1958 - December 20, 1958, HSPT-REL-94-527, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2511

Note: An H Division Annual Progress Report for 1958 was not located during project research activities.

1959 Health Division Reports

Shipman, T. L., 1959a, H Division Monthly Progress Report, H-285, December 20, 1958 - January 20, 1959, HSPT-REL-94-528, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2512

Shipman, T. L., 1959b, H Division Monthly Progress Report, H-287, January 20, 1959 - February 20, 1959, HSPT-REL-94-529, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2513

Shipman, T. L., 1959c, H Division Monthly Progress Report, February 20, 1959 - March 20, 1959, HSPT-REL-94-531, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2739

Shipman, T. L., 1959d, H Division Monthly Progress Report, March 20, 1959 - April 20, 1959, HSPT-REL-94-532, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2514

Shipman, T. L., 1959e, H Division Monthly Progress Report, April 20, 1959 - May 20, 1959, HSPT-REL-94-534, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2515

Shipman, T. L., 1959f, H Division Monthly Progress Report, May 20, 1959 - June 20, 1959, HSPT-REL-94-908, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2424

Shipman, T. L., 1959g, H Division Monthly Progress Report, June 20, 1959 - July 21, 1959, HSPT-REL-94-909, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2425

Shipman, T. L., 1959h, H Division Monthly Progress Report, July 21, 1959 - August 21, 1959, HSPT-REL-94-911, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2426

Shipman, T. L., 1959i, H Division Monthly Progress Report, August 20, 1959 - September 20, 1959, HSPT-REL-94-912, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2427

Shipman, T. L., 1959j, H Division Monthly Progress Report, September 20, 1959 - October 20, 1959, HSPT-REL-94-482, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2492

LASL (Los Alamos Scientific Laboratory), 1959a, H Division Monthly Progress Report, October 20, 1959 - November 20, 1959, HSPT-REL-94-483, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2493

LASL (Los Alamos Scientific Laboratory), 1959b, H Division Monthly Progress Report, H-295, November 20, 1959 - December 20, 1959, HSPT-REL-94-486, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2494

Note: An H Division Annual Progress Report for 1959 was not located during project research activities.

1960 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1960a, H Division Monthly Progress Report, H-296, December 20, 1959 - January 20, 1960, HSPT-REL-94-487, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2495

Shipman, T. L., 1960a, H Division Monthly Progress Report, H-297, January 20, 1960 - February 20, 1960, HSPT-REL-94-488, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2496

Shipman, T. L., 1960b, H Division Monthly Progress Report, February 20, 1960 - March 20, 1960, HSPT-REL-94-491, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2497

LASL (Los Alamos Scientific Laboratory), 1960b, H Division Monthly Progress Report, H-298, March 20, 1960 - April 20, 1960, HSPT-REL-94-492, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2498

LASL (Los Alamos Scientific Laboratory), 1960c, H Division Monthly Progress Report, April 20, 1960 - May 20, 1960, HSPT-REL-94-537, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2516

LASL (Los Alamos Scientific Laboratory), 1960d, H Division Monthly Progress Report, May 20, 1960 - June 20, 1960, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4946

Shipman, T. L., 1960c, H Division Monthly Progress Report, June 20, 1960 - July 20, 1960, HSPT-REL-94-914, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2428

Shipman, T. L., 1960d, H Division Monthly Progress Report, July 20, 1960 - August 20, 1960, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4947

Shipman, T. L., 1960e, H Division Monthly Progress Report, H-299, August 20, 1960 - September 20, 1960, HSPT-REL-94-916, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2429

Shipman, T. L., 1960f, H Division Monthly Progress Report, September 20, 1960 - October 20, 1960, HSPT-REL-94-918, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2430

Shipman, T. L., 1960g, H Division Progress Report, October 20, 1960 - November 20, 1960, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4948

Shipman, T. L., 1960h, H Division Monthly Progress Report, November 20, 1960 - December 20, 1960, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4949

Note: An H Division Annual Progress Report for 1960 was not located during project research activities.

1961 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1961a, H Division Monthly Progress Report, December 20, 1960 - January 20, 1961, HSPT-REL-94-539, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2517

LASL (Los Alamos Scientific Laboratory), 1961b, H Division Monthly Progress Report, January 20, 1961 - February 20, 1961, HSPT-REL-94-541, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2518

LASL (Los Alamos Scientific Laboratory), 1961c, H Division Monthly Progress Report, February 20, 1961 - March 20, 1961, HSPT-REL-94-542, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2519

LASL (Los Alamos Scientific Laboratory), 1961d, H Division Monthly Progress Report, March 20, 1961 - April 20, 1961, HSPT-REL-94-544, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2520

LASL (Los Alamos Scientific Laboratory), 1961e, H Division Monthly Progress Report, April 20, 1961 - May 20, 1961, HSPT-REL-94-546, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2521

LASL (Los Alamos Scientific Laboratory), 1961f, H Division Monthly Progress Report, May 20, 1961 - June 20, 1961, HSPT-REL-94-548, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2522

LASL (Los Alamos Scientific Laboratory), 1961g, H Division Monthly Progress Report, June 20, 1961 - July 20, 1961, HSPT-REL-94-549, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2523

LASL (Los Alamos Scientific Laboratory), 1961h, H Division Monthly Progress Report, July 20, 1961 - August 20, 1961, HSPT-REL-94-551, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2524

LASL (Los Alamos Scientific Laboratory), 1961i, H Division Monthly Progress Report, August 20, 1961 - September 20, 1961, HSPT-REL-94-552, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2525

LASL (Los Alamos Scientific Laboratory), 1961j, H Division Monthly Progress Report, September 20, 1961 - October 20, 1961, HSPT-REL-94-553, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2813

LASL (Los Alamos Scientific Laboratory), 1961k, H Division Monthly Progress Report, October 21, 1961 - November 20, 1961, File # 00131187 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4950

LASL (Los Alamos Scientific Laboratory), 1961l H Division Monthly Progress Report, November 21, 1961 - December 20, 1961, HSPT-REL-94-554, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2526

Note: An H Division Annual Progress Report for 1961 was not located during project research activities.

1962 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1962a, H Division Monthly Progress Report, December 21, 1961 - January 20, 1962, HSPT-REL-94-555, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2527

LASL (Los Alamos Scientific Laboratory), 1962b, H Division Monthly Progress Report, January 21, 1962 - February 20, 1962, HSPT-REL-94-556, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2528

LASL (Los Alamos Scientific Laboratory), 1962c, H Division Monthly Progress Report, February 21, 1962 - March 20, 1962, HSPT-REL-94-595, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2529

LASL (Los Alamos Scientific Laboratory), 1962d, H Division Monthly Progress Report, March 21, 1962 - April 20, 1962, HSPT-REL-94-596, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2530

LASL (Los Alamos Scientific Laboratory), 1962e, H Division Monthly Progress Report, April 21, 1962 - May 20, 1962, HSPT-REL-94-597, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2531

LASL (Los Alamos Scientific Laboratory), 1962f, H Division Monthly Progress Report, May 21, 1962 - June 20, 1962, HSPT-REL-94-598, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2532

Note: An H Division Monthly Progress Report for June 21 - July 20, 1962 was not located during project research activities.

Stoll, R. D., 1962, H Division Monthly Progress Report, July 21, 1962 - August 20, 1962, HSPT-REL-94-599, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2533

LASL (Los Alamos Scientific Laboratory), 1962g, H Division Monthly Progress Report, August 21, 1962 - September 20, 1962, HSPT-REL-94-600, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2534

LASL (Los Alamos Scientific Laboratory), 1962h, H Division Monthly Progress Report, September 21, 1962 - October 20, 1962, HSPT-REL-94-601, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2535

Note: An H Division Monthly Progress Report for October 21 - November 20, 1962 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1962i, H Division Monthly Progress Report, November 21, 1962 - December 20, 1962, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4951

Note: An H Division Annual Progress Report for 1962 was not located during project research activities.

1963 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1963a, H Division Monthly Progress Report, December 21, 1962 - January 20, 1963, HSPT-REL-94-499, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2499

LASL (Los Alamos Scientific Laboratory), 1963b, H Division Monthly Progress Report, January 21, 1963 - February 20, 1963, HSPT-REL-94-500, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2500

LASL (Los Alamos Scientific Laboratory), 1963c, H Division Monthly Progress Report, February 21, 1963 - March 20, 1963, HSPT-REL-94-501, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2501

Shipman, T. L., 1963a, H Division Monthly Progress Report, March 21, 1963 - April 20, 1963, HSPT-REL-94-602, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2536

Shipman, T. L., 1963b, H Division Monthly Progress Report, April 21, 1963 - May 20, 1963, HSPT-REL-94-603, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2537

Shipman, T. L., 1963c, H Division Monthly Progress Report, May 21, 1963 - June 20, 1963, HSPT-REL-94-604, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2538

Shipman, T. L., 1963d, H Division Monthly Progress Report, June 21, 1963 - July 20, 1963, HSPT-REL-94-605, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2539

Stoll, R. D., 1963, H Division Monthly Progress Report, July 21, 1963 - August 20, 1963, HSPT-REL-94-607, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2540

LASL (Los Alamos Scientific Laboratory), 1963d, H Division Monthly Progress Report, August 21, 1963 - September 20, 1963, HSPT-REL-94-608, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2541

Note: An H-Division Progress Report for September 21 - October 20, 1963 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1963e, H Division Monthly Progress Report, October 21, 1963 - November 20, 1963, HSPT-REL-94-502, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2502

LASL (Los Alamos Scientific Laboratory), 1963f, H Division Monthly Progress Report, November 21, 1963 - December 20, 1963, HSPT-REL-94-503, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2503

Note: An H Division Annual Progress Report for 1963 was not located during project research activities.

1964 Health Division Reports

Shipman, T. L., 1964, H Division Monthly Progress Report, December 21, 1963 - January 20, 1964, HSPT-REL-94-609, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2812

Note: An H Division Monthly Progress Report for January 21 – February 20, 1964 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1964a, H Division/Group H-1 Monthly Progress Report (memorandum from M.A. Frechette to D.D. Meyer), January 21, 1964 - February 20, 1964, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4529.

LASL (Los Alamos Scientific Laboratory), 1964b, H Division Monthly Progress Report, February 21, 1964 - March 20, 1964, HSPT-REL-94-504, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2504

Note: An H Division Monthly Progress Report for March 21 - April 20, 1964 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1964c, H Division Monthly Progress Report, April 21, 1964 - May 20, 1964, HSPT-REL-94-505, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2505

Note: An H Division Monthly Progress Report for May 21 - June 20, 1964 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1964d, H Division/Group H-1 Monthly Progress Report (memorandum from D.A. McKown to D.D. Meyer), May 21, 1964 - June 19, 1964, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4529.

LASL (Los Alamos Scientific Laboratory), 1964e, H Division Monthly Progress Report, June 21, 1964 - July 20, 1964, HSPT-REL-94-507, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2506

LASL (Los Alamos Scientific Laboratory), 1964f, H Division/Group H-1 Monthly Progress Report (memorandum from M.F. Dean to D.D. Meyer), June 20, 1964 – July 20, 1964, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4529

LASL (Los Alamos Scientific Laboratory), 1964g, H Division Monthly Progress Report, July 21, 1964 - August 21, 1964, HSPT-REL-94-508, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2507

LASL (Los Alamos Scientific Laboratory), 1964h, H Division Monthly Progress Report, August 21, 1964 - September 20, 1964, HSPT-REL-94-509, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2508

Note: An H Division Monthly Progress Report for September 21 - October 20, 1964 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1964i, H Division/Group H-1 Monthly Progress Report (memorandum from D.E. Hankins to D.D. Meyer), September 21, 1964 – October 20, 1964, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4529

LASL (Los Alamos Scientific Laboratory), 1964j, H Division/Group H-1 Monthly Progress Report (memorandum from J.E. Dummer to D.D. Meyer), October 21, 1964 – November 20, 1964, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4529

Note: H Division Monthly Progress Reports for October 21 - November 20, 1964 and November 21, 1964 – December 20, 1964 were not located during project research activities.

Note: An H Division Annual Progress Report for 1964 was not located during project research activities.

1965 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1965a, H Division Monthly/Quarterly Progress Report, January - March, 1965. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No.6262.

LASL (Los Alamos Scientific Laboratory), 1965b, H Division Monthly/Quarterly Progress Report, April - June 1965. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6263.

LASL (Los Alamos Scientific Laboratory), 1965c, H Division Monthly/Quarterly Progress Report, July -September, 1965. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6264.

LASL (Los Alamos Scientific Laboratory), 1965d, H Division Monthly/Quarterly Progress Report, October - December, 1965. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6265.

1966 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1966a, H Division Monthly/Quarterly Progress Report, January - March, 1966. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6266.

LASL (Los Alamos Scientific Laboratory), 1966b, H Division Monthly/Quarterly Progress Report, April - June 1966. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6267.

LASL (Los Alamos Scientific Laboratory), 1966c, H Division Monthly/Quarterly Progress Report, July -September, 1966. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6268

LASL (Los Alamos Scientific Laboratory), 1966d, H Division Monthly/Quarterly Progress Report, October - December, 1966. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6269.

1967 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1967a, H Division Monthly/Quarterly Progress Report, January - March, 1967. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6270.

LASL (Los Alamos Scientific Laboratory), 1967b, H Division Monthly/Quarterly Progress Report, April - June 1967. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6271.

LASL (Los Alamos Scientific Laboratory), 1967c, H Division Monthly/Quarterly Progress Report, July -September, 1967. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6272

LASL (Los Alamos Scientific Laboratory), 1967d, H Division Monthly/Quarterly Progress Report, October - December, 1967. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6273.

1968 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1968a, H Division Monthly/Quarterly Progress Report, January - March, 1968. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6274.

LASL (Los Alamos Scientific Laboratory), 1968b, H Division Monthly/Quarterly Progress Report, April - June 1968. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. 6275.

LASL (Los Alamos Scientific Laboratory), 1968b, H Division Monthly/Quarterly Progress Report, July - Spetember 1968. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. 817.

LASL (Los Alamos Scientific Laboratory), 1968c, H Division Monthly/Quarterly Progress Report, October - December, 1968. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6276.

1969 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1969a, H Division Monthly/Quarterly Progress Report, January - March, 1969. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6277.

LASL (Los Alamos Scientific Laboratory), 1969b, H Division Monthly/Quarterly Progress Report, April - June 1969. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6278.

LASL (Los Alamos Scientific Laboratory), 1969c, H Division Monthly/Quarterly Progress Report, July -September, 1969. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6279.

LASL (Los Alamos Scientific Laboratory), 1969d, H Division Monthly/Quarterly Progress Report, October - December, 1969. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. Nos. 4182 and 6280.

1970 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1970a, H Division Monthly/Quarterly Progress Report, January - March, 1970. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6281.

LASL (Los Alamos Scientific Laboratory), 1970b, H Division Monthly/Quarterly Progress Report, April - June 1970. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6282.

LASL (Los Alamos Scientific Laboratory), 1970c, H Division Monthly/Quarterly Progress Report, July -September, 1970. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6283.

Note: Monthly or quarterly H Division Progress reports for the period October - December, 1970 were not located during project research activities.

1971 Health Division Reports

Voelz, G. L., 1971a, H Division Progress Report, January - March 1971, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4704

Voelz, G. L., 1971b, H Division Progress Report, April - June 1971, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4705

Voelz, G. L., 1971c, H Division Progress Report, July - September 1971, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4878

Voelz, G. L., 1972a, H Division Progress Report, October - December 1971, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4991

1972 Health Division Reports

Voelz, G. L., 1972b, H Division Progress Report, January - March 1972, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4992

Voelz, G. L., 1972c, H Division Progress Report, April - June 1972, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4990

Note: Quarterly Progress Reports for July – September 1972 and October – December 1972 was not located during project research activities.

1973 and 1974 Health Division Reports

Note: H-Division Quarterly Progress Reports from third quarter of 1972 through 1980 were not located during the project. Quarterly reports were located for 1981 and second quarter 1982. Additional H-Division reports for this time period and later were not located during project research activities.

1981 Health Division Reports

LASL (Los Alamos Scientific Laboratory), 1981b, Health Division Quarterly Report, January - March 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 936

LASL (Los Alamos Scientific Laboratory), 1981c, Health Division Quarterly Report, April - June 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 936

LASL (Los Alamos Scientific Laboratory), 1981d, Health Division Quarterly Report, July - September 1981; Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 5603

LASL (Los Alamos Scientific Laboratory), 1981e, Health Division Quarterly Report, October - December 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 935

1982 Health Division Reports

LANL (Los Alamos National Laboratory), 1982, Health Division Quarterly Report, April – June 1982, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 3689

Note: Quarterly Progress Reports for January – March, 1981 and July – December, 1981 were not located during project research activities.

Note: Starting the third quarter of 1972, LASL began to publish quarterly and monthly Health Physics reports.

1972 Health Physics Reports

Meyer D.D. 1972a. Quarterly Progress Report – Group H-1 Health Physics, July – September 1972, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4985.

Meyer D.D. 1972b. Quarterly Progress Report – Group H-1 Health Physics, October - December 1972, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. 4986.

1973 Health Physics Reports

Meyer D.D. 1972b. Quarterly Progress Report – Group H-1 Health Physics, January – March 1973, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4987.

Meyer D.D. 1972b. Quarterly Progress Report – Group H-1 Health Physics, April – June 1973, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4988.

Valentine, A., 1973, Quarterly Progress Report for October – December, 1973 for Operational Health Physics, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5453.

1975 Health Physics Reports

Dummer, J.E., 1975a, Quarterly Progress Report – Group H-1 Health Physics, July – September 1975, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392a

Dummer, J.E., 1975b, Quarterly Progress Report – Group H-1 Health Physics, October - December 1975, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 448

1976 Health Physics Reports

Dummer, J.E., 1977a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392b

Dummer, J.E., 1977b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392c

Dummer, J.E., 1977c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392d

Dummer, J.E., 1977d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392e

1977 Health Physics Reports

Dummer, J.E., 1977a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392b

Dummer, J.E., 1977b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392c

Dummer, J.E., 1977c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392d

Dummer, J.E., 1977d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392e

Note: Starting in the third quarter of 1978, Area Heath Physics (Group H-1) began reporting activities in separate monthly and quarterly reports. The last report with these titles that were located during the project is for January 1981 activities.

1978 Health Physics Reports

Dummer, J.E., 1978a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392f

Dummer, J.E., 1978b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392g

Dummer, J.E., 1978c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392h

Dummer, J.E., 1978d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392i

Note: Starting in the third quarter of 1978, Area Heath Physics began reporting activities in separate monthly and quarterly reports.

Dummer, J.E., 1978e, Area Health Physics Monthly Report, July 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5470

Dummer, J.E., 1978f, Area Health Physics Monthly Report, August 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5560

Dummer, J.E., 1978g, Area Health Physics Monthly Report, September 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5561

Dummer, J.E., 1978h, Area Health Physics Monthly Report, October 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5562

Dummer, J.E., 1978i, Area Health Physics Monthly Report, November 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5563

Dummer, J.E., 1978j, Area Health Physics Monthly Report, December 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5583

1979 Health Physics Reports

Dummer, J.E., 1979a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392j

Dummer, J.E., 1979b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392k

Dummer, J.E., 1979c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392l

Dummer, J.E., 1979d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392m.

Dummer, J.E., 1979e, Area Health Physics Monthly Report, January 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5473

Dummer, J.E., 1979f, Area Health Physics Monthly Report, February 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. 5474

Dummer, J.E., 1979g, Area Health Physics Monthly Report, March 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5475

Dummer, J.E., 1979h, Area Health Physics Monthly Report, April 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5476

Dummer, J.E., 1979i, Area Health Physics Monthly Report, May 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5477

Dummer, J.E., 1979j, Area Health Physics Monthly Report, June 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5478

Dummer, J.E., 1979k, Area Health Physics Monthly Report, July 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5479

Dummer, J.E., 1979l, Area Health Physics Monthly Report, August 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5480

Dummer, J.E., 1979m, Area Health Physics Monthly Report, September 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5481

Dummer, J.E., 1979n, Area Health Physics Monthly Report, October 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5566

Dummer, J.E., 1979o, Area Health Physics Monthly Report, November 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5568

Dummer, J.E., 1980a, Area Health Physics Monthly Report, December 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5567

1980 Health Physics Reports

Dummer, J.E., 1980a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392n

Dummer, J.E., 1980b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392o

Dummer, J.E., 1980c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392p

Dummer, J.E., 1980d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392q

Note: Starting in the third quarter of 1978, Area Heath Physics began reporting activities in separate monthly reports.

Dummer, J.E., 1980e, Area Health Physics Monthly Report, January 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5569

Dummer, J.E., 1980f, Area Health Physics Monthly Report, February 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5570

Dummer, J.E., 1980e, Area Health Physics Monthly Report, March 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5571

Dummer, J.E., 1980e, Area Health Physics Monthly Report, April 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5572

Dummer, J.E., 1980e, Area Health Physics Monthly Report, May 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5573

Dummer, J.E., 1980e, Area Health Physics Monthly Report, June 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5574

Dummer, J.E., 1980e, Area Health Physics Monthly Report, July 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5575

Dummer, J.E., 1980e, Area Health Physics Monthly Report, August 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5576

Dummer, J.E., 1980e, Area Health Physics Monthly Report, September 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5577

Dummer, J.E., 1980e, Area Health Physics Monthly Report, October 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5578

Dummer, J.E., 1980e, Area Health Physics Monthly Report, November 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5579

Dummer, J.E., 1980e, Area Health Physics Monthly Report, December 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5580

1981 Health Physics Reports

Dummer, J.E., 1981a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392r

Dummer, J.E., 1981b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 448

Dummer, J.E., 1981c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 448

Dummer, J.E., 1981d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 448, 5580

Note: Starting in the third quarter of 1978, Area Heath Physics began reporting activities in separate monthly reports.

Miller, J., Gallimore, J., Stafford, R., 1981a, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, January 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5581

Miller, J., Gallimore, J., Stafford, R., 1981b, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, February 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5582

Miller, J., Gallimore, J., Stafford, R., 1981c, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, March 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5584

Miller, J., Gallimore, J., Stafford, R., 1981d, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, April 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5585

Miller, J., Gallimore, J., Stafford, R., 1981e, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, May 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5586

Miller, J., Gallimore, J., Stafford, R., 1981f, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, June 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5587

Miller, J., Gallimore, J., Stafford, R., 1981g, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, July 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5588

Miller, J., Gallimore, J., Stafford, R., 1981h, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, August 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5589

Miller, J., Gallimore, J., Stafford, R., 1981i, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, September 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5590

Miller, J., Gallimore, J., Stafford, R., 1981j, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, October 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5591

Miller, J., Gallimore, J., Stafford, R., 1981k, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, November 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5592

Miller, J., Gallimore, J., Stafford, R., 1981l, Health Physics - Group H-1, Monthly Progress Report - Area Health Physics, December 1981, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5593

1982 Health Physics Reports

Dummer, J.E., 1982a, Health Physics Quarterly Progress Report, January - March 1982, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6102

Dummer, J.E., 1982b, Health Physics Quarterly Progress Report, April - June 1982, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6103

Dummer, J.E., 1982c, Health Physics Quarterly Progress Report, July - September 1982, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6104

Dummer, J.E., 1982d, Health Physics Quarterly Progress Report, October - December 1982, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6105

1983 Health Physics Reports

Dummer, J.E., 1983a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392s

Note: Quarterly Progress Reports – Group H-1 Health Physics for April – June 1983, July – September 1983, and October – December 1983 were not located during project research activities.

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, January 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5653

Miller, J., Gallimore, J., Stafford, R., 1983b, Health Physics Monthly Activity Reports - Operational, February 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5654

Miller, J., Gallimore, J., Stafford, R., 1983c, Health Physics Monthly Activity Reports - Operational, March 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5655

Miller, J., Gallimore, J., Stafford, R., 1983d, Health Physics Monthly Activity Reports - Operational, April 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5656

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, May 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5657

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, June 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5659

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, July 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5658

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, August 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5660

Note: September 1983 Health Physics Monthly Activity Reports were not located during project research activities.
Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, October 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5661

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, November 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5662

Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, December 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5663

1989 Health Physics Reports

Valentine, A. 1989c, Radiation Protection Quarterly Report, October – December 1989, Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 392aa

1990 Health Physics Reports

Graf, J.M. 1990a, Radiation Protection Quarterly Report, April - June 1990, Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. No. 392bb

Graf, J.M. 1990b, Radiation Protection Quarterly Report, July - September 1990, Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. No. 392cc

Graf, J.M. 1990c, Radiation Protection Quarterly Report, October - December 1990, Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. No. 392dd

1991 Health Physics Reports

Graf, J.M. 1991, Radiation Protection Quarterly Report, October - December 1990, Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. No. 392ee

1975 EHS Reports

LASL (Los Alamos Scientific Laboratory), 1975a, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, January - March, 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6239

LASL (Los Alamos Scientific Laboratory), 1975b, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, April - June 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6240

Note: A Quarterly Progress Report, Operational Environmental, Health, and Safety Activities for July - September 1975 was not located during project research activities.

Note: A Quarterly Progress Report, Operational Environmental, Health, and Safety Activities for October – December 1975 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1975c, Quarterly Progress Report, Health Research Division – Indirect Laboratory Support Activities, January - March 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4993

LASL (Los Alamos Scientific Laboratory), 1975d, Quarterly Progress Report, Health Research Division – Indirect Laboratory Support Activities, April - June 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4994

1976 EHS Reports

LASL (Los Alamos Scientific Laboratory), 1976a, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, January - March, 1976. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6241

LASL (Los Alamos Scientific Laboratory), 1976b, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities April - June 1976. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6242

Note: A Quarterly Progress Report for July - September 1976 was not located during project research activities

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1977 EHS Reports

LASL (Los Alamos Scientific Laboratory), 1977a, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, January - March, 1977. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6237

LASL (Los Alamos Scientific Laboratory), 1977b, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, April - June 1977. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6238

LASL (Los Alamos Scientific Laboratory), 1977c, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, July -September, 1977. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6235

LASL (Los Alamos Scientific Laboratory), 1977d, Quarterly Progress Report, Operational Environmental, Health, and Safety Activities, October - December, 1977. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6236

1978 ESH Reports

Voelz, George L., 1978a, Quarterly Progress Report: January - March, 1978 Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. No. 893

Voelz, George L., 1978b, Quarterly Progress Report: Operational Environmental Safety and Health Activities April - June, 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. No. 896b

Voelz, George L., 1978c, Quarterly Progress Report: Operational Environmental Safety and Health Activities July-September, 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6234.

Voelz, George L., 1978d, Quarterly Progress Report: Operational Environmental Safety and Health Activities October - December, 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 6244.

1979 ESH Reports

Voelz, George L., 1979a, Quarterly Progress Report, January - March 1979, Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. No. 941

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Voelz, George L., 1979d, Quarterly Progress Report, October - December 1979, Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 941

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Voelz, George L., 1980a, Quarterly Progress Report, January - March 1980 Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 937

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LASL (Los Alamos Scientific Laboratory), 1981a, Health Division Quarterly Report, October - December 1980, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 933.

1987 HSE Reports

LANL (Los Alamos National Laboratory), 1987, Health, Safety, Environment Quarterly Report, July - September 1987, Los Alamos, New Mexico. Repos. No. 3126.

1988 HSE Reports

LANL (Los Alamos National Laboratory), 1988a, Health, Safety, Environment Quarterly Report, January - March 1988, Los Alamos, New Mexico. Repos. No. 1246.

LANL (Los Alamos National Laboratory), 1988b, Health, Safety, Environment Quarterly Report, October - December 1988, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 5913

1989 HSE Reports

LANL (Los Alamos National Laboratory), 1989, Health Safety Environment Quarterly Report, April - June 1989, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 3570

1990 HSE Reports

LANL (Los Alamos National Laboratory), 1990, Health Safety Environment Update, Summary of 1990 Quarterly Reports, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 878

Chapter 14: Environmental Monitoring at LANL

This chapter presents a summary of environmental monitoring and research data that may be useful for evaluating historical releases from LANL. The reports and monitoring data reviewed by the LAHDRA project team represent samples or measurements collected in both on-site and off-site areas potentially affected by past contaminant releases from LANL operations. The information presented here is organized chronologically to highlight changes and improvements that have occurred during the evolution of LANL's environmental monitoring programs since the start of LANL's operations in 1943. Details on monitoring practices presented in this chapter are more heavily weighted toward pre-1970 monitoring, since the largest releases occurred during this time period.

Overall information availability is summarized in the following sections. Brief descriptions of several example environmental studies that are tied to past LANL activities are included. It is important to note that, while this chapter summarizes a number of environmental monitoring studies, it is not a complete historical record of every study conducted to date. Many more environmental studies are described and referred to in documents selected by the LAHDRA project team and added to the project information database.

Areas of Investigation

Environmental monitoring and research data reviewed by the LAHDRA project team primarily address sampling and measurement of environmental media, such as air, water, soils, sediments, biota, and foodstuffs that were potentially impacted by radioactive and chemical contaminants released from LANL. Monitoring data of interest to this project represent measured concentrations of contaminants at on-site and off-site locations, including areas along the site boundary and residential communities that are nearby, regional, or useful for characterizing background concentrations. Historically, these data have typically been used by LANL to monitor trends in contaminant releases and/or to study the presence, migration, and fate of releases that have occurred or are occurring through transport mechanisms, such as air dispersion, leaching, or surface flow to important water resources. Environmental monitoring data are of interest for potentially filling data gaps that exist in historical effluent monitoring data for various discharge points at LANL.

The following section describes the primary geographical areas of interest during the investigation. These areas were selected for investigation based on:

- The LAHDRA project team's knowledge of the key release sources at LANL,
- Previous environmental studies of on-site and off-site areas,
- Surface waters that have received past LANL emissions,
- Reported areas of contaminant accumulation in surface water, sediments, and surface and subsurface soils,
- Annual airborne releases and indications of how they have been affected by local and regional wind patterns, as well as local and regional topography, and
- Historical environmental surveillance and monitoring and a review of environmental data availability.

Some environmental monitoring within the laboratory boundary and surrounding areas began within the first few years after the start of LANL operations in 1943. Monitoring was first conducted by members of the Health Group of Project Y, the United States Atomic Energy Agency, and the U.S. Geological Survey (USGS). In more recent years, other LANL divisions and the state of New Mexico have also conducted environmental monitoring and/or environmental studies. Most of the early monitoring involved collecting non-routine air, water, soil, and sediment samples that were then analyzed for radioactive and, occasionally, elemental or chemical contaminants. The early environmental monitoring program was used to identify and characterize the spread of radioactive contamination to surrounding land areas, and to estimate potential radiation exposures to workers as a result of laboratory activities and emissions.

Increased monitoring over the years meant collecting a larger number of routine samples for all types of media and for a growing list of contaminants. The frequencies with which samples were collected also increased over the years. With the advent of new environmental protection and emission standards in the early 1970s, LANL saw the need to further increase its monitoring of the environment both on and off site, and to enhance the formats with which it reported measurement results. The need to do more monitoring was also brought to LANL's attention by independent reviewers and experts (Parker, 1974).

Based on reports reviewed to date, most of the emphasis for environmental monitoring during the early years was placed on measuring radioactive constituents; however, beginning in the late 1950s, some limited sampling was performed for lead, mercury, chromium, beryllium, and other elements and chemicals of interest. Early environmental documents pointed out the need to increase sampling for all media, and to perform radiochemical analyses for isotopic plutonium and specific fission products

associated with fall-out from atmospheric weapon tests to better differentiate between global fallout and LANL impacts (Parker, 1974).

The areas of concern for the investigation of environmental data include:

- Los Alamos community
- Española community
- White Rock community
- Surrounding Native American lands
- Los Alamos Canyon
- DP Canyon
- Pueblo Canyon
- Acid Canyon
- Rio Grande River
- Mortandad Canyon
- Bayo Canyon
- Pajarito Canyon
- Sandia Canyon
- Guaje Canyon
- Area reservoirs

Conditions at LANL and Surrounding Areas

The laboratory site and adjacent communities are situated on the Pajarito Plateau, which consists of a series of mesas separated by deep canyons. These canyons were cut by intermittent streams that trend south-eastward from an altitude of about 2,400 m at the Jemez Mountains to about 1,800 m at the eastern margin, where they terminate above the Rio Grande Valley. The canyons and mesas areas are underlain by the Bandelier Tuff, and are composed of the ashfall, ashflow pumice, and rhyolite tuff that form the surface of Pajarito Plateau. The volcanic ash was deposited following an eruption that occurred about 1.2 million years ago (LASL, 1980).

Surface waters are primarily intermittent streams that begin on the sides of the Jemez Mountains and supply base flow to the upper reaches of some canyons. The amount of flow in these streams is typically insufficient to maintain flow across the laboratory area before it is depleted by evaporation, transpiration, and infiltration. However, runoff from heavy thunderstorms and significant snowmelts reaches the Rio

Grande several times a year. Over portions of LANL's operational history, its effluents have provided sufficient volume to maintain surface flow in the canyons for distances up to 1.5 km (LASL, 1980). Several photographs of LANL discharges to area canyons are shown in Fig. 14-1.

Fig. 14-1. Discharges of liquid radioactive waste to Acid Canyon in the mid-1940s (left) and to DP Canyon in 1973. *Photographs courtesy of LANL.*

Groundwater occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in the canyons, (2) perched water in basalt, and (3) the main aquifer of the Los Alamos area. Deposited alluvium in the canyons ranges in thickness from 1 to 30 m, and is quick permeable in contrast to the underlying volcanic tuff and sediments, resulting in a shallow alluvial groundwater that moves down gradient in the alluvium and becomes depleted as it moves into the underlying volcanic deposits. In lower Los Alamos and Pueblo Canyons, a small local body of perched water is formed in the basalts by water filtration. This water discharges in the Los Alamos Canyon west of the Rio Grande. The main aquifer capable of municipal water supply rises westward from the Rio Grande within the Tesuque Formation into the lower part of the Puye Formation beneath the central and western part of the plateau. Depth to the aquifer decreases from 360 m along the western margin of the Plateau to about 180 m at the eastern margin. The water is under water table conditions in the western and central part of the plateau, and under artesian conditions in the eastern part and along the Rio Grande (LASL, 1980).

Availability of Environmental Data

Much of the environmental monitoring results reported for years prior to 1970 and reviewed by the project team are published in letter-type reports that vary widely in terms of content and detail. In some cases, only a portion of a report was available for review, or a report may only contain limited amounts of monitoring data, or may lack a description of the methods and purpose for a monitoring activity. Information presented in these earlier documents indicates that environmental monitoring was sporadic, and generated a smaller amount of data when compared to results for later years, when monitoring activities were much more formalized and comprehensive.

By the late 1950s, LANL attempted to formally consolidate environmental monitoring results into one report. One of the first such reports is titled "Los Alamos Environmental Monitoring Program" for the years 1959 and 1960. This report includes results for direct gamma measurements, air particulate sampling for analysis of alpha and beta air concentrations, and water sampling of potable water supplies, surface body waters, and test monitoring wells (LASL, 1960). Not until 1970, however, when LANL began to publish its annual environmental surveillance reports, were results of monitoring activities routinely reported in a unified and comprehensive manner. Monitoring grew substantially over the next 35 years, with results published and documented in the annual environmental monitoring reports. Many of these annual reports are now available to the public on LANL's Web site at www.lanl.gov.

Chronology of Early Environmental Monitoring at LANL (1943 – 1970)

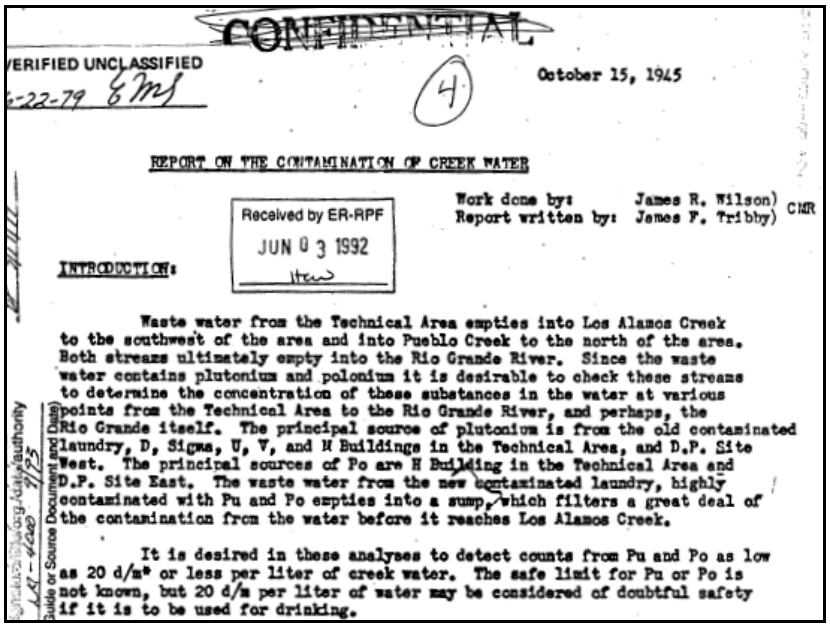
Documents indicate that LANL began its first environmental monitoring activities sometime in 1944 or 1945. Monitoring was designed to measure radioactive and chemical concentrations in water, sediments, and soils, with the intent of defining the impacts to the environment from laboratory liquid waste discharges to nearby canyons or burial grounds. The monitoring program evolved in the 1950s, and expanded to include additional sampling and radiation surveys. Along with increases in water and soil sampling locations and sample collection frequencies, LANL began routine gamma radiation measurements and air sampling for gaseous and particulate radionuclides or non-radioactive contaminants. LANL periodically reported results for these early sampling and radiation survey activities in brief letter-reports. Reports often presented combined results for water and soil samples, ambient gamma measurements, and air samples (Tribby, 1945, Kingsley, 1947, Tribby, 1947, Kennedy, 1965). Occasionally, LANL reported results for radioactive fallout particulates from LANL operations using "Sticky trays" with gummed-paper to collect the radioactive contamination (Kennedy, 1958). These early sampling activities were sporadic, and often involved non-routine monitoring to study changes in contaminant concentrations over time, as well as contaminant movement in the environment.

An independent safety appraisal of the LANL health and safety program conducted in 1947 by the Safety and Industrial Health Advisory Board of the National Safety Council was highly critical of LANL's ability to control and monitor hazardous material releases to the environment (Williams and Board, 1948). In addition, LANL documents indicate that environmental monitoring lacked continuity and consistency in terms of sampling methods, data analysis, and reporting. Using staff from various groups operating somewhat independently from one another made it difficult to compile routine data into unified and consistent formats with the desired level of data and reporting quality (Kennedy, 1958). Effluent and environmental monitoring programs were not as well developed as the methods and practices used for monitoring personnel radiation exposures during this time period, and it is evident that the health and safety program was primarily directed towards reducing radiation exposures to workers. Documents available to the project team indicate that routine environmental air sampling was almost nonexistent until the mid to late 1950s.

Monitoring of Liquid Waste Releases

During early operations in the 1940s, liquid waste from the DP site (TA-21) and the Original Technical Area (TA-1) were released into Los Alamos Canyon and Pueblo Canyon. Periodic water and sediment samples were collected in the canyon creeks and drainage areas and in off-site areas such as the Rio Grande and analyzed for radioactive and chemical contaminant concentrations. Liquid effluent samples were also collected at discharge points to determine if the amounts of waste released were within the legal or recommended concentration limits for the time, which were also used at the Hanford site (Tribby, 1948). Many of the samples during this time were analyzed for plutonium, polonium, uranium, beta and gamma, and occasionally for heavy metals and other elements such as lead, bismuth, mercury, chromium, and fluorine (Tribby, 1945, Kingsley, 1947, Kingsley and Tribby, 1947, Schnap and Tribby, 1948, Shipman, 1958).

Area supply wells and other potable water supplies were also sampled and tested (Wilson and Tribby, 1945). The liquid effluent limits at that time were 6.3×10^{-4} μCi L^{-1} for plutonium and polonium and 5.0×10^{-1} μCi L^{-1} for mixed fission products such as ^{140}La and ^{140}Ba. The earliest LANL documents describing initial monitoring activities and results covered the period 1945 to 1950 (Tribby, 1945, 1947, Schnap and Tribby, 1948). Treatment of the liquid waste was initially minimal, but did increase as production and liquid waste volumes increased (Tribby, 1948). The following excerpt from a LANL document depicts the sources of contamination and environmental areas targeted for sampling (Tribby, 1945).



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October 15, 1945

(4)

REPORT ON THE CONTAMINATION OF CREEK WATER

Work done by: James R. Wilson)
Report written by: James F. Tribby) CMR

Received by ER-RPF
JUN 03 1992

INTRODUCTION:

Waste water from the Technical Area empties into Los Alamos Creek to the southwest of the area and into Pueblo Creek to the north of the area. Both streams ultimately empty into the Rio Grande River. Since the waste water contains plutonium and polonium it is desirable to check these streams to determine the concentration of these substances in the water at various points from the Technical Area to the Rio Grande River, and perhaps, the Rio Grande itself. The principal source of plutonium is from the old contaminated laundry, D, Sigma, U, V, and M Buildings in the Technical Area, and D.P. Site West. The principal sources of Po are H Building in the Technical Area and D.P. Site East. The waste water from the new contaminated laundry, highly contaminated with Pu and Po empties into a sump, which filters a great deal of the contamination from the water before it reaches Los Alamos Creek.

It is desired in these analyses to detect counts from Pu and Po as low as 20 d/m* or less per liter of creek water. The safe limit for Pu or Po is not known, but 20 d/m per liter of water may be considered of doubtful safety if it is to be used for drinking.

Building or Source Document and Date)

Fig. 14-2. Excerpt from a LANL document depicting the sources of contamination and environmental areas targeted for sampling (Tribby, 1945)

Water sampling was usually conducted after heavy rains, since creek beds were often dry during seasonal periods of low precipitation. Many of the samples were collected in "pools" of liquid waste discharges and rainwater in lower-lying or down gradient drainage areas (Kingsley, 1947). Concentrations for radioactive contaminants in water and soil samples were typically elevated at locations near effluent discharge points in the canyons, and decreased to undetectable levels within short distances from discharge points. Elevated levels were often identified during periods of liquid discharge, but concentrations would decrease over time because of decaying short-lived radionuclides such as polonium, or because of dilution and movement of longer-lived radioactive contaminants dispersed within surface waters during periods of moderate to heavy precipitation (Kingsley, 1947, Schnap and Tribby, 1948). Records indicate that to reduce contaminants levels released to the canyons or burial grounds, LANL began to scale back on its liquid waste discharges to Los Alamos and Pueblo Canyons as additional waste treatment facilities at the laboratory became operational.

LANL found it necessary to expand its waste treatment capacity as growing production and research demands generated larger and larger volumes of liquid and solid radioactive and chemical waste. H-7 group became part of the H Division in June, 1955, and assumed responsibility for liquid waste treatment and management. The H-7 Group also oversaw a growing environmental monitoring program in those areas potentially impacted by liquid and airborne discharges. Two liquid waste treatment plants used co-

precipitation for removing plutonium, and one plant was equipped with an ion exchange unit to remove barium-140 and radioactive strontium isotopes (Shipman, 1958).

The Waste Treatment Plant at TA-45 received wastes from TA-1 and TA-3 and discharged treated liquid waste to Acid canyon; 11.5 million gallons of waste, for example, were received in 1957. Treatment of the waste removed roughly 94% of the radioactivity and 99% of the plutonium, which allowed the Treatment Plant to meet 10% of the NBS 52 Handbook tolerance for plutonium discharge (Shipman, 1958). More treatment capacity was added as necessary, and as releases of contaminants decreased over time.

The Ten Site Waste Treatment plant at TA-35 handled liquid waste for the RaLa program with four 50,000 gallon tanks. Wastes contained mixtures of ^{140}Ba, ^{140}La, ^{89}Sr, ^{90}Sr, ^{90}Y and trace amounts of other radionuclides. Waste treatment removed 93% of radioactivity, and discharged roughly 92% of liquid waste volume to Mortandad Canyon after treatment (Shipman, 1958).

In coordination with LANL, the United States Geological Survey (USGS) also collected routine water samples from local surface streams, the Rio Grande, supply wells, and monitoring wells, and submitted the samples to LANL for radiochemical and water quality analyses. Monthly samples were analyzed for gross alpha, gross beta, plutonium, and uranium. Samples were also analyzed for pH, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO_3, and conductivity. Volumetric flow rates for streams located in Pueblo and Los Alamos canyons are also presented in study results. These additional samples were also used to assess the potential impacts from LANL operations on water resources, and to better understand the rate and direction of groundwater flow in the local and regional area (Griffin, 1956, Shipman, 1956).

By the 1970s, LANL was conducting water sampling at various locations at distances of 40 to 50 km away from the main laboratory area (LASL, 1971). Additional examples of early environmental monitoring studies of waterborne contamination are presented in a later section of this chapter.

Soil Monitoring

LANL also conducted soil sampling at on-site and off-site locations to further assess impacts from liquid waste discharges from TA-1 and TA-21. Soil samples were collected in areas along canyon creeks or in dry creek beds and drainage areas. Samples were often analyzed for plutonium, polonium, uranium, beta and gamma heavy metals and other elements, such lead mercury, chromium, and fluorine (Tribby, 1945). Soil sampling results were reported, along with results of water monitoring activities. Concentration

results at on-site locations close to discharge points were often reported above detection limits or background levels. Results for sampling locations at greater from discharge points were often reported as "negative," meaning that either concentration levels were below the method detection limits for analytical measurement techniques used at the time, or they were below an administrative or regulatory control limit (Kennedy, 1952).

Results for soil samples collected in Acid Canyon (discharge from TA-45 plant), Mortandad Canyon (discharge from TA-35 plant), Los Alamos Canyon (discharge from TA-21), and at the laundry site were periodically reported in Health Division reports or memoranda (Shipman, 1958). Samples during this time period were analyzed according to location: gross alpha and plutonium at Acid and Los Alamos Canyons, and ^{90}Sr and yttrium at Mortandad Canyon.

In 1955, soil sample results showed strontium contamination in the upper reaches of Mortandad Canyon that exceeded NBS Handbook tolerance levels (Shipman, 1958). A study of plutonium, strontium, and cesium movement in tuff materials began during 1957 and reported that very little radioactive material movement had occurred based upon comparison to sampling results for the previous years. Soil sampling continued throughout the 1950s and beyond. Results consistently showed strontium contamination in the canyon resulting from Ten Site liquid waste discharges (Shipman, 1956).

Grab and composite surface water samples were collected at various locations along the Rio Grande River and the Chama River. The rivers had a reported natural uranium background concentration of approximately 10^{-9} μCi cm^{-3}. Water samples were also collected at seven perennial streams, 13 water supply wells, and eight test monitoring wells located in various canyons within and surrounding the laboratory (Shipman, 1956). In 1957, LANL began a study to evaluate the movement of ^{90}Sr, ^{137}Cs, and ^{239}Pu released form LANL through the local soils, including tuff material (Shipman, 1958).

By the 1970s, LANL was conducting soil and sediment sampling at various locations 40 to 50 km away from the site (LASL, 1971). Additional examples of early soil contaminant monitoring and sampling studies are presented in a later section of this chapter.

Air Monitoring

A variety of air monitoring activities and measurements conducted by LANL were also used as another means of assessing impacts from routine or accidental air effluents from laboratory operations or from re-suspension of radioactively-contaminated soils or dry sediments. The primary focus of LANL's early air monitoring program from 1944 to around 1970 was to detect larger, accidental releases, and, as such,

routine sampling results at or below detection limits were not reported on a regular basis. These early monitoring stations were equipped with thin-walled GM tubes and a scaler/rate m to record results. By the late 1950s and 1960s, air particulate filters and charcoal canisters were being used at most of these stations to measure gross alpha and beta and radioactive iodine concentrations in air. Routine reporting of these early measurements also appear to be sporadic and limited in terms of the amount of data presented in LANL documents. Only a limited amount of air monitoring results for 1940s and 1950s and, to some extent the 1960s, apparently were published by LANL. It is also possible that results were published in reports that are now missing, were destroyed, or simply were not located by the project team. Based on available documents reviewed by the project team, routine reporting of monitoring results, however, does not appear to have begun in earnest until 1970.

LANL did not have a well established network of air monitoring stations until the late 1950s, and documents indicate that 25 to 36 monitoring stations were used from 1958 to 1992. Most of these stations were located on-site within the various Technical Areas at LANL, within the Los Alamos town site, or within the town's immediate surrounding areas. The two on-site monitoring stations furthest away from the Main Technical area or Los Alamos town site were located in White Rock, New Mexico (approximately 6 mi to the southeast) and at the eastern site boundary. The report entitled "Los Alamos Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, January through June, 1971" (the predecessor report to LANL's Annual Environmental Surveillance reports) indicates that LANL began to use two remote "off-site" air monitoring stations starting sometime in 1971. One station was placed in Española, New Mexico, approximately 14 mi northeast of Los Alamos, and the other station was located in Santa Fe, New Mexico, approximately 24 mi southeast of Los Alamos (LASL, 1972).

In 1992 and 1993, LANL expanded the number of on-site monitoring stations to 52, including the addition of regional or remote stations at various locations up to approximately 45 mi northeast of LANL. The collective array of air monitoring stations became known as AIRNET monitoring program. During this expansion of air monitoring stations, LANL also increased the network to six off-site or remote monitoring stations. The remote stations since that time were located in Española, San Ildefonso Pueblo, El Rancho, and Jemez Pueblo New Mexico, and they are still being used by LANL. An additional monitoring station was added within the Santa Fe city limits. In 2003, LANL added a seventh remote monitoring station at Picuris Pueblo, New Mexico, making it the station furthest away from LANL, at roughly 45 mi to the northeast. Most of these AIRNET stations or predecessor monitoring stations are still in operation today, although routine or periodic reporting of monitoring results did not begin until the 1970s with the advent of LANL's Annual Environmental Surveillance reports (LANL, 1994, 2008).

Starting around the early to mid-1960s, air filters were measured for gross alpha and beta activities and then made into composite samples once a month for isotopic analyses of long-lived alpha-emitting radionuclides such as plutonium. Charcoal canisters also continued to be analyzed for ^{131}I by way of gamma measurements, and water vapor was measured for tritium concentrations via liquid scintillation counting.

A comparison of environmental air monitoring programs at other DOE sites shows that LANL used similar measurement techniques throughout the years, although they did not establish remote, off-site monitoring as early as some DOE sites. For example, the Oak Ridge Reservation (ORR) sites (X-10, Y-12, and K-25) used a formal network of local and perimeter ("on-site") samplers and monitors during the 1940s and 1950s, but also began using remote ("off-site") gamma and air monitoring stations in the early 1960s. Eventually, the networks of monitoring stations were officially referred to as the local air monitors (LAMs), perimeter air monitors (PAMs), and remote air monitors (RAMs). ORR's LAM and PAM monitoring stations used during this early period were equipped with ion-chamber type instruments to measure outdoor ambient gamma radiation levels. These instruments were later modified to measure beta radiation, although laboratory staff discovered the instruments were highly susceptible to weathering and proved to be unreliable for routine measurements. ORR eventually used GM tubes with scaler/rate m to measure both gamma and beta radiation. Charcoal canisters were used at selected stations for iodine measurements, and tritium measurements were performed on rain water samples. Similar to the practices used by LANL, ORR also used film badges and TLDs in later years to measure gamma and beta radiation, and air samplers to measure particulate and gaseous airborne concentrations of radioactive materials in order to determine impacts from site effluents and/or global nuclear fallout.

ORR used three remote air monitoring (RAM) stations as far back as 1956. These stations were also equipped with GM Tubes and scalers, gummed-paper trays and rain collectors for measuring air particulate radioactive contaminants/fallout, and charcoal canisters for measuring radioactive iodine. The first three RAMs used were located in Corryton and Kingston, Tennessee, and Berea, Kentucky. The Corryton and Kinston stations were only used in 1956, and data for the Berea station is only available for 1957 and 1958. Use of the Berea station was discontinued in 1962. Prior to 1959, seven additional remote air monitoring stations were added at various Tennessee Valley Authority (TVA) dam locations, ranging in distance from approximately 12 to 75 mi from the ORR (ORAU Team, 2004). In comparison, LANL's primary focus during early air monitoring was not on remote locations as much as it was on monitoring impacts to local residential areas and nearby canyons. It wasn't until around 1970 that LANL began to expand its air monitoring network beyond its site boundary.

Bayo Canyon (TA-10) and TA-35 – RaLa Test Shots

LANL documents from the 1940s and early 1950s indicate that initial air monitoring conducted by LANL was focused on monitoring radioactive fallout from the RaLa test shots conducted in Bayo Canyon. Radioactive and chemical debris from test shots containing ^{140}Ba and ^{140}La was released to the atmosphere using dispersion rates and directional patterns based on weather conditions at the time of each shot. Airborne contaminants would typically migrate beyond Bayo Canyon to surroundings areas. As discussed in a 1945 LANL document, the three primary hazards associated with RaLa shots included external radiation, explosive materials, and airborne contamination. Airborne contamination initially was monitored at the firing location and at other points in the canyon and on the Los Alamos mesa by members of Group A-6 (Steinhardt, 1945). Measurements were made with film badges mounted three feet above the ground surface on wooden or metal stakes. Direct gamma measurements were also collected with a GM tube and a scaler/rate m. Later, fallout trays with gummed-paper were used to collect radioactive debris.

Radioactive fallout from most test shots was monitored to the extent practical as LANL acknowledged that some downwind areas surrounding Bayo Canyon were inaccessible because of the area's rugged terrain. Following test shots, the road from the Main Tech area (TA-1) to the East Gate was often closed to vehicle traffic to allow time for radioactive contamination to be removed or decay to levels deemed acceptable for resumption of public access to the roads. The radioactive plume from a RaLa shot conducted on April 20, 1949, for example, passed over and contaminated the area from the East Main Gate to Los Alamos town site. The incident required decontaminating the main road (Highway 285) before it could be reopened to the public or other workers. Because of these incidences, LANL sought to improve its weather and fallout predictions by requesting assistance from meteorologists from the Kirkland Air Force Base in Albuquerque (LASL, 1949c).

Debris from another shot on May 20 of the same year drifted out of the canyon and contaminated the main road to Los Alamos at the Frijoles junction, resulting in maximum gamma-beta readings of 10 mR h^{-1} (LASL, 1949a). Throughout this time period, staff from the Biophysics section focused their efforts on further defining and predicting fallout from the RaLa shots to minimize exposures to workers and members of the public. In 1949, the fallout problem became more acute when LANL discovered a new mining operation in Guaje Canyon operated by the Santa Fe Pumice Company located about three mi away from Bayo Canyon. To minimize the spread of contamination and better characterize potential environmental and public health impacts from RaLa test shots, LANL increased its efforts to measure wind rose patterns, including prevailing wind directions and maximum and average wind velocities of

prevailing winds (LASL, 1949b). As reported in a 1949 monthly H Division progress report, the plume from an implosion test shot rose and spread contamination easterly as far as ten mi away at a location known as "Camp May" (LASL, 1949d).

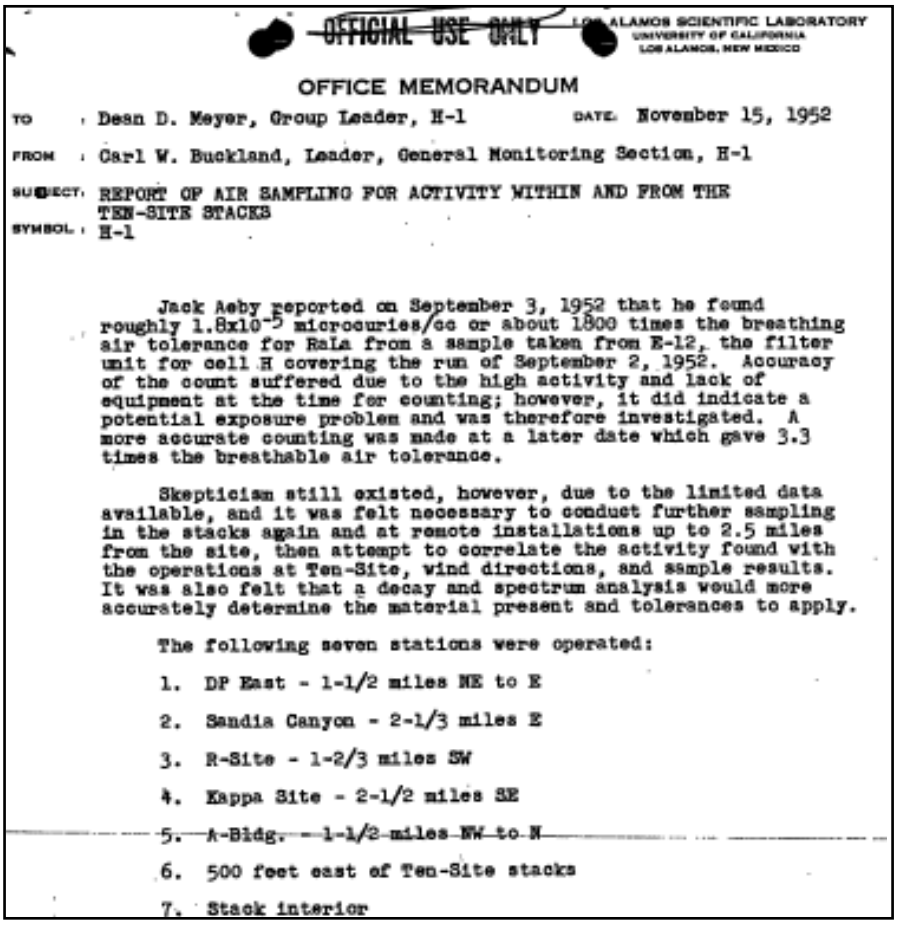
Descriptions in the 1952 H Division annual report indicate that LANL continued to monitor dispersion and fallout of radioactive material from Bayo Canyon test shots. These surveys focused on tracking contamination in areas north and east of Bayo Canyon, White Rock, Totavi, Puje, and Espanola, and addressed growing concerns about releases from RaLa shots and from other facilities (such as DP Site) as production increased significantly during this period. The report noted that additional sampling was conducted along East Road to assess impacts and hazards from DP Site as well as from Bayo Canyon releases. Health Division members from the H-1 and H-6 monitoring groups also expanded the on-site and off-site monitoring program to further address the growing concerns about environmental impacts (Shipman, 1953).

Laboratory safety personnel also expressed concerns about personnel and public exposures associated with RaLa test shots, as well as airborne effluents from RaLa hot cell operations and operations at TA-2 (Omega), TA-3 (CMR Building), and TA-21 (DP Sites). The TA-35 hot cell facility was used to handle, store, and prepare the RaLa sources for test shots conducted in Bayo Canyon. The excerpt from a 1952 LANL document shown in

Fig. 14-3 represents another example of LANL activities used during this time to assess the impacts from the TA-35 radioactive airborne effluents (Aeby, 1954).

The excerpt from a 1952 LANL document shown in

Fig. 14-4 further indicates that LANL staff was aware of the importance of predicting weather conditions to minimize the spread of radioactive contamination and so conducted periodic surveys to determine impacts of air effluents (Aeby, 1954). Other means of tracking cloud dispersions from the RaLa shots was by using air conductivity measurement. This technique proved to have advantages over using GM tube instruments, particularly when radiation fields approached saturation levels (LASL, 1951). Based on our review of project documents, it is not clear to what extent LANL used conductivity measurements for tracking radioactive, explosive cloud dispersions.



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LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

OFFICE MEMORANDUM

TO : Dean D. Meyer, Group Leader, H-1 DATE: November 15, 1952

FROM : Carl W. Buckland, Leader, General Monitoring Section, H-1

SUBJECT: REPORT OF AIR SAMPLING FOR ACTIVITY WITHIN AND FROM THE TEN-SITE STACKS

SYMBOL : H-1

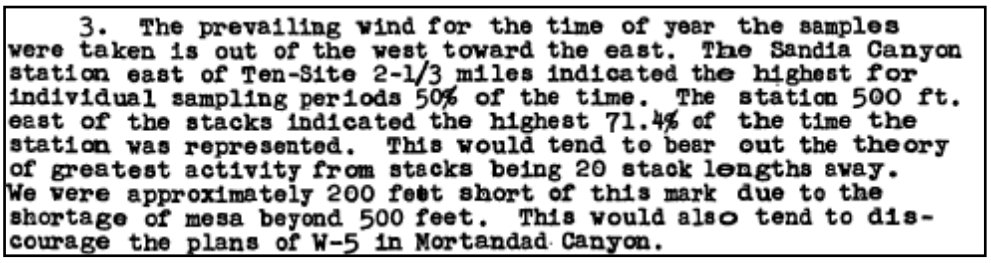
Jack Aeby reported on September 3, 1952 that he found roughly 1.8×10^{-5} microcuries/cc or about 1800 times the breathing air tolerance for RaLa from a sample taken from E-12, the filter unit for cell H covering the run of September 2, 1952. Accuracy of the count suffered due to the high activity and lack of equipment at the time for counting; however, it did indicate a potential exposure problem and was therefore investigated. A more accurate counting was made at a later date which gave 3.3 times the breathable air tolerance.

Skepticism still existed, however, due to the limited data available, and it was felt necessary to conduct further sampling in the stacks again and at remote installations up to 2.5 miles from the site, then attempt to correlate the activity found with the operations at Ten-Site, wind directions, and sample results. It was also felt that a decay and spectrum analysis would more accurately determine the material present and tolerances to apply.

The following seven stations were operated:

1. DP East - 1-1/2 miles NE to E
2. Sandia Canyon - 2-1/3 miles E
3. R-Site - 1-2/3 miles SW
4. Kappa Site - 2-1/2 miles SE
5. ~~A-Bldg. - 1-1/2 miles NW to N~~
6. 500 feet east of Ten-Site stacks
7. Stack interior

Fig. 14-3. Excerpt from a 1952 document describing measurements of airborne radioactivity from RaLa processing at TA-35 (Aeby, 1954)



3. The prevailing wind for the time of year the samples were taken is out of the west toward the east. The Sandia Canyon station east of Ten-Site 2-1/3 miles indicated the highest for individual sampling periods 50% of the time. The station 500 ft. east of the stacks indicated the highest 71.4% of the time the station was represented. This would tend to bear out the theory of greatest activity from stacks being 20 stack lengths away. We were approximately 200 feet short of this mark due to the shortage of mesa beyond 500 feet. This would also tend to discourage the plans of W-5 in Mortandad Canyon.

Fig. 14-4. Excerpt from a 1952 LANL document describing wind patterns and dispersion of airborne effluents (Aeby, 1954)

In a series of reports and memoranda from 1956 to 1959, outdoor air concentration and radiation level monitoring within and surrounding TA-35 continued to be used to assess impacts from airborne effluents associated with $^{140}Ba/^{140}La$ source production, LAPRE operations, and irradiated reactor fuel analyses (including fission products) and plutonium experiments in hot cells (Griffin, 1956). Availability of these environmental monitoring data are limited based on document searches conducted by the project team. These types of data could be useful as a tool for evaluating the accuracy of effluent estimates reported by the lab or release estimates derived from basic effluent measurement data. Further research, including document searches for these early environmental data, is recommended as part of any future dose reconstruction study of LANL operations.

Main Technical Area and Greater Los Alamos and Surrounding Areas

In 1951, LANL continued to discuss the need to expand its air sampling program to improve its ability to measure contamination in areas outside of the Main Technical Area and DP Site resulting from laboratory activities. Health Division staff were recommending continuous operation of sampling stations at numerous locations adjacent to Los Alamos (LASL, 1952).

In 1954, LANL used ten air particulate monitoring stations within the Los Alamos community to measure airborne alpha concentrations during the demolition of D-Building (Johnson, 1954). Additional on-site stations were also used to study impacts from LANL operations, with a focus on detecting and/or measuring radioactive releases from TA-1 (Main Technical Area), TA-2 (Omega reactor), TA-3 (CMR Building), TA-21 (DP Sites), TA-35 (RaLa hot cells, LAPRE, etc), and TA-10 (Bayo Canyon). During that same year, 14 air samplers were used at locations in the Main Technical Area (TA-1), and in the Los Alamos town site, including residential areas and along the site perimeter (LASL, 1954a). The locations of the 14 air monitoring stations included:

1636 34th Street	South Mesa Road – Contractor Area
194 Abbey Street	Adjacent to Foundry Building at TA-1
861 43rd Street	Roof of O Building at TA-1
2135 35th Street	Roof of V-Shop at TA-1
2500B 36th	Roof of HRL Building at TA-1
2379B Ivy Street	Roof of Gamma Building at TA-1
331A Manhattan Loop	Warehouse 18 at TA-1

Measurement results for 1954 were presented in two data sets (LASL, 1954a, 1954b). Monitoring results for previous years were not identified by the project team, but further research to locate relevant records

would likely be warranted during any future LANL dose reconstruction investigation. A thorough evaluation of the quality of these data is warranted if it is to be used in the future for evaluating the accuracy of effluent release estimates.

In 1959, LANL proposed increasing air sampling for particulates to assess impacts from LANL operations on the surrounding communities by placing additional air samples on the rooftops of schools within the Los Alamos community (Kennedy, 1959). By 1960, LANL's air environmental monitoring program had grown to 15 sampling locations for monitoring airborne alpha contamination (including plutonium and polonium) and for assessing any environmental impacts from laboratory operations (LASL, 1960). During 1965 the number of sampling locations expanded to 25 air stations positioned within the Los Alamos residential areas and population centers (such as schools) and along perimeter roads throughout LANL's various technical areas. As was the case during previous environmental air sampling activities, these samplers were used to measure airborne particulates and short-lived radioactive gases routinely released from LANL, or for detecting large amounts of radioactive material released during accidents (Kennedy, 1965).

The air samplers used during this period contained two separate filter media to test for beta and gamma radioactivity. Mine Safety Appliance (MSA) 4-inch diameter CR-17651 respirator particulate filters were analyzed for beta (fallout) activity using a gas proportional counter calibrated with a $^{90}Sr/^{90}Y$ standard. Samples were collected on a daily basis, and also periodically merged into composite samples for analysis of ^{90}Sr, ^{137}Cs, and ^{144}Ce. An MSA BM 2306 charcoal canister was mounted behind the particulate filter and used for measuring gamma (radioiodine) activity. The charcoal canisters were measured for iodine activity on a gamma spectrometer calibrated with a ^{131}I standard (Kennedy, 1965).

A second air particulate sampler was used for measuring long-lived alpha activity, such as plutonium. Samples were collected on a Gelman AM-3, two inch diameter filters and analyzed on a gas proportional counter calibrated to a ^{239}Pu standard. Samples were held for one week prior to counting to allow for the decay of natural radon and thoron. The lower limit of detection for these air samples was 4×10^{-15} μCi cm^{-3}, or one-tenth the regulatory limit (4×10^{-14} μCi cm^{-3}) used at that time. If results exceeded the regulatory limit, then samples were analyzed for radionuclide concentrations using alpha spectroscopy. A maximum value of 2×10^{-14} μCi cm^{-3} was reported for 1959 and 1960, with the average result falling below the method detection limit. A charcoal canister was also used on a percentage of these air samplers, but documents with a full or partial set of sampling results were not identified during documents performed during the project (Kennedy, 1965).

In 1993, LANL expanded the number of monitoring stations to 52, including regional locations as far away as Picuris Pueblo, New Mexico, located roughly 45 mi northeast of LANL (LASL, 1960, LANL, 2008).

Global Nuclear Fallout Measurements

Around 1958, LANL began specifically collecting air particulate and rain water samples for analyzing beta radioactivity concentrations and performing gamma radiation measurements as part of the U.S. Public Health Service (PHS) program for reporting nuclear fallout data. LANL was one of eleven U.S Atomic Energy Commission sites to participate in the monitoring program, and used one monitoring station located on the roof of laboratory's Administration Building, SM-43 at TA-3, for this purpose (Kennedy, 1960). The PHS program had a total of 44 monitoring stations located throughout the United States. Results were reported for airborne beta activity (pCi m^{-3}), rain water radioactivity (pCi m^{-2}), and gamma radiation (mR h^{-1}).

Results for the LANL nuclear fallout monitoring station are reported in a series of annual laboratory reports for the years 1958 to 1970 titled "Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico" or "Beta Radioactivity in Environmental Air at Los Alamos, New Mexico" (see Table 14-1). Reports that contain pre-1958 sampling results were not located during this project, although it is believed LANL may have conducted these types of measurements prior to these publications. Reported monitoring results for measured concentrations or radiation levels were typically consistent with background radiation levels or expected nuclear fallout amounts, and did not show elevated levels from LANL operations. However, the monitoring station was located west or north and most often upwind of LANL's primary production areas (e.g., TA-3, TA-10, TA-21, TA-35), and would not have been expected to routinely collect and measure activity released from these LANL process operations.

In March, 1963, the H-8 monitoring group relocated their offices to TA-50 and moved the fallout air station to the roof of their new building, located about 1.5 mi southeast of the TA-3 Administration Building (Aeby and Kennedy, 1964).

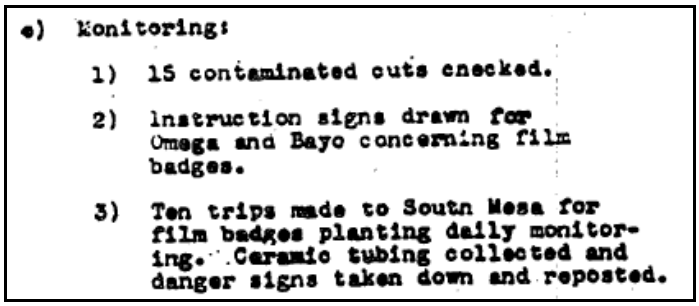
In 1964, LANL published results for long-lived fission products measured in rain water and air particulate samples continuously collected from 1958 through 1963. The purpose of the report was to describe isotopic analyses of composite samples and to present concentration values for ^{90}Sr, ^{137}Cs, and radioactive rare earth elements (Graham, 1964).

Table 14-1. LANL publications on nuclear fallout measurements

- Radioactivity in Environmental Air at Los Alamos, New Mexico for the Period November 17, 1958 - December 31, 1959. LAMS-2397 (Kennedy, 1960).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1960. LAMS-2499 (Kennedy 1961).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1st Quarter 1961. ER37183. Los Alamos, New Mexico. (Kennedy, 1961a).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1961. LAMS-2702 (Kennedy, 1962).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1962. LAMS-2870. (Aeby and Kennedy, 1963).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1963. LAMS-3071. (Aeby and Kennedy, 1964).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1964. LAMS-3245. (Aeby and Kennedy, 1965).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1965. LAMS-3516. (Aeby and Kennedy, 1966).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1966. LAMS-3663. (Aeby and Kennedy, 1967).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1967. LA-3887. (Aeby and Kennedy, 1968).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1968. LA-4133. (Aeby and Kennedy, 1969).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1969. LA-4388. (Aeby and Kennedy, 1970).
- Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1970. LA-4661. (Aeby and Kennedy, 1971).

Gamma Monitoring

Direct gamma exposure rates or integrated gamma measurements were used to further define changes in environmental conditions as a result of airborne and waterborne releases from LANL operations. As described in a 1948 monthly H Division report, film badges on South Mesa were planted for daily monitoring (see Fig. 14-5) (LASL, 1948). No further details on when this monitoring began are provided in the report, and a search for these monitoring data did not identify any additional records. These types of data could provide useful, supplemental information regarding impacts from early effluents during the 1940s, and could be used to assess direct radiation exposures for periods when effluent amounts are difficult to ascertain because of a lack of effluent monitoring data.



e) Monitoring:

1) 15 contaminated cuts checked.

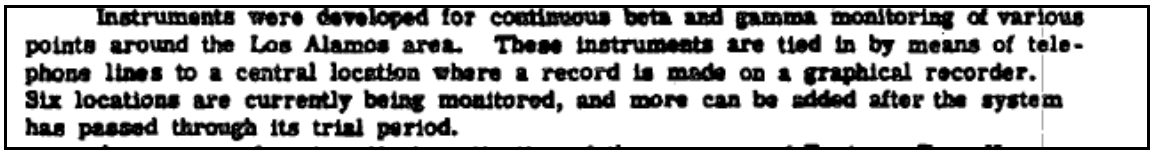
2) Instruction signs drawn for Omega and Bayo concerning film badges.

3) Ten trips made to South Mesa for film badges planting daily monitoring. Ceramic tubing collected and danger signs taken down and reposted.

Fig. 14-5. Document excerpt discussing planting of film badge dosimeters on South Mesa (LASL, 1948)

Descriptions in another 1948 monthly H Division progress report indicate that the film badges where placed on top of South Mesa to monitor radioactive cloud dispersion associated with RaLa implosion test shots carried out in Bayo Canyon (LASL, 1948).

Sometime during 1949, direct gamma and beta exposure rates were monitored using Geiger-Mueller (G-M) instruments with continuous monitoring and telemetry that reported results to a central location (see Fig. 14-6). These instruments were deployed in the Los Alamos area at six separate locations to provide another method for monitoring changes to the outside environment resulting from LANL operations (Shipman et al., 1950).



Instruments were developed for continuous beta and gamma monitoring of various points around the Los Alamos area. These instruments are tied in by means of telephone lines to a central location where a record is made on a graphical recorder. Six locations are currently being monitored, and more can be added after the system has passed through its trial period.

Fig. 14-6. Document excerpt discussing development of instruments for beta-gamma monitoring around Los Alamos (Shipman et al., 1950)

Sometime during the 1950s, the six stations were expanded to seven locations as described in a 1959 LANL report. Twenty-four hour continuous readings were transmitted through telephone lines to a central recording station located at the main Administration Building. The transmitted readings were documented on automatic chart recorders. Variations in radiation levels were identified, and most often determined to be attributable to variations in natural background radiation. It appears that these monitors remained in service throughout the 1960s and perhaps longer. A directed search for a complete set of these measurement results was unsuccessful during the project.

During the 1950s, beta and gamma monitors were designed and built at the laboratory to assess impacts from releases from the Omega Water Boiler reactor, though their specific locations were not indicated in the report (LASL, 1950).

Additional ambient gamma exposure levels were routinely measured with film badges mounted on stakes 1 m above the ground surface. These badges were exchanged on a monthly basis. The film's reported sensitivity was above ambient background levels and approached the Radiation Protection Guide value used during this period. Any measurable dose recorded was then attributed to LANL effluents or other man-made sources of radiation (e.g., nuclear weapon test fallout). For 1960, 2400 gamma measurements were reported, and, with the exceptions of two locations, all results were less than the 0.5 rem, the public dose limit used at the time, and recommended by the Federal Radiation (Federal Radiation Council, 1960, Kennedy, 1961). Records that contain detailed results of these measurements were not identified during the project.

By 1965, LANL used thermoluminescent dosimeters (TLDs) at 100 locations throughout the Los Alamos residential areas and surrounding areas on LANL property. The dosimeters were used to assess ambient gamma radiation levels and detect potential impacts from radionuclide emissions from the laboratory, particularly larger releases associated with accidents or other uncontrolled events (Kennedy, 1965). The dosimeters were collected and analyzed on a monthly basis. A directed search for pre-1970 measurement results was unsuccessful during the project. By 1970, LANL reduced the number of TLD stations to 60 locations based on prior measurement experience (e.g., redundancy of adjacent monitoring locations) and the recognition that for future monitoring, one location provided adequate spatial coverage in some areas that had used two to three TLDs during prior monitoring periods. However, LANL increased the number of TLD locations again in 1981, and has maintained more than 150 since that time.

Summary of Annual Environmental Surveillance Reports (1970 – 2007)

Beginning in 1970, as environmental monitoring increased, LANL began to publish annual reports for environmental monitoring results based on sampling and analyses conducted by LANL staff and the USGS. These reports contain monitoring results for a variety of environmental sample types, including:

- direct radiation readings for alpha, beta, and gamma radiation,
- outdoor/external thermoluminescent dosimeters (TLDs),
- surface water including drainage ditches, creeks, ponds, rivers, and lakes,
- ground water,

- particulate and gaseous air sampling,
- soil and sediment sampling,
- food sources,
- assorted biota and wildlife, and
- special environmental sampling and research studies.

In the early 1970s, environmental samples were collected and analyzed by LANL's Environmental Services Group. Table 14-2 identifies the annual reports that have been published, and Table 14-3 presents a summary of chemical and radionuclide monitoring data that are available in the annual environmental surveillance reports.

Table 14-2. Annual environmental monitoring and surveillance reports

Beginning in 1970, LANL began publishing annual reports describing annual environmental monitoring results of media sampled both on-site and off-site at the laboratory. The data contained in these reports represent a wide range of sample types and sampling frequencies, and vary according to the priorities and emphasis placed on monitoring and surveillance during a given year. Annual reports available for review during this and any future health studies are listed below.

Period	LANL Report No.	LAHDRA Repos. No.
January - June 1970	none	1000
July - December 1970	LA-4672-MS	2178
January - June 1971	LA-4871-MS	4079
July - December 1971	LA-4970	4079
1972	LA-5184	4078
1973	LA-5586	2161
1974	LA-5977-PR	2133
1975	LA-6321-MS	2158
1976	LA-6801-MS	2159
1977	LA-7263-MS	2069
1978	LA-7800-ENV	953
1979	LA-8200-ENV	2190
1980	LA-8810-ENV	930
1981	LA-9349-ENV	929
1982	LA-9762-ENV	1314
1983	LA-10100-ENV	2342
1984	LA-10421-ENV	654
1985	LA-10721-ENV	1319
1986	LA-10992-ENV	4074
1987	LA-11306-ENV	4075
1988	LA-11628-ENV	4076
1989	LA-12000-ENV	1088
1990	LA-12271-MS	2311
1991	LA-12572-ENV	2189
1992	LA-12764-ENV	1089
1993	LA-12973-ENV	3903
1994	LA-13047-ENV	3857
1995	LA-13210-ENV	3849
1996	LA-13343-ENV	4077
1997	LA-13487-ENV	3863
1998	LA-13633-ENV	3892
1999	LA-13775-ENV	3873
2000	LA-13861-ENV	3875
2001	LA-13979-ENV	6198
2002	LA-14085-ENV	6199
2003	LA-14162-ENV	6200
2004	LA-14239-ENV	6201
2005	LA-14304-ENV	7989
2006	LA-14341-ENV	7990
2007	LA-14369-ENV	7991

Data contained in the annual reports represent samples routinely collected in air, surface water, ground water, soils, sediments, a variety of biota, and some food sources. The laboratory did not perform any measurements of food sources until the later part of the 1970s. The annual reports also contain information about special studies conducted to provide better coverage of areas of particular interest, or to study in detail individual sources of contamination. For example, a study of radionuclide uptake in garden plants grown in the Mortandad Canyon was initiated in 1976 and reported in the "Environmental Surveillance at Los Alamos During 1977" report (LASL, 1978b). Additional descriptions of the types of monitoring data contained in the annual reports are presented below.

Examples of Early Environmental Studies of Interest

This section presents various environmental monitoring and research data that describe the historical presence and behavior of contaminants in off-site areas around LANL. Media addressed include surface water, sediment, ambient air, aquatic and terrestrial foodstuffs, soil, drinking water, and groundwater. Hydrologic and meteorological data are also presented below. Descriptions of additional studies will be added to this section as more information becomes available to the project team.

Historical Surface Water and Sediment Data

Sample of available surface water and sediment monitoring data collected in areas of concern described in the above section are presented below. Because of the large volumes of data, not all of the available data have been summarized for this report.

Study #1: Radioactivity in Los Alamos and Pueblo Creek (1945-1947) – Some of the earliest measurement results for samples collected from wastewaters released from the Technical Area into Pueblo and Los Alamos Canyons are reported. Samples were collected at various points along the creeks, which terminated at the Rio Grande River about 0.25 mi downstream of Otowi Bridge (Tribby, 1945, 1947). Samples were analyzed for plutonium and polonium. A detection limit of 20 disintegrations per minute per liter of creek water was reported at that time. One-liter samples were collected at each location and submitted to a counting laboratory for analyses.

Sampling	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995-2007
Airborne releases- rad.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Airborne releases- chem.											•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- gross alpha	•	•	•	•	•	•	•	•	•	•	•	•	•									•	•	•	•
Air- gross beta	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- ^{241}Am			•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- ^{238}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- ^{239}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- ^{234}U	•	•																				•	•	•	•
Air- ^{235}U	•	•																				•	•	•	•
Air- ^{238}U	•	•																				•	•	•	•
Air- total U	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- ^{131}I	•	•														•						•	•	•	
Air- ^{41}Ar		•																							
Air- ^{3}H	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air- beryllium	•	•																				•	•	•	•
Air- lead	•	•																							
Air- cadmium	•	•																							
Air stations (#)	58	35	36	26	26	29	30	25	25	25	25	25	26	26	26	26	26	25	27	28	36	36	52	52	46 - 50+
Fish- ^{238}Pu					•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fish- ^{239}Pu					•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fish- ^{137}Cs					•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fish- ^{90}Sr												•	•	•	•	•	•		•	•	•	•	•	•	•
Fish- uranium									•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fruits- ^{238}Pu					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fruits- ^{239}Pu					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fruits- ^{137}Cs																•	•	•		•	•	•	•	•	•
Fruits- ^{90}Sr									•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
Fruits- tritium						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fruits- uranium					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Groundwater- Rad.			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Groundwater- Chem.				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Liquid releases- Rad.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Liquid releases- Chem.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Meteorlogical data[a]	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Milk- Rad.					•	•																			•
Municipal liq. discharge	•	•	•	•	•	•																			
Sediment- gross alpha	•	•	•	•	•	•	•	•	•	•	•	•									•	•	•	•	•
Sediment- gross beta	•	•	•	•	•	•	•	•	•	•	•	•									•	•	•	•	•
Sediment- gross gamma													•	•	•	•	•				•	•	•	•	•
Sediment- ^{238}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sediment- ^{239}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sediment- ^{241}Am	•																				•	•	•	•	•
Sediment- ^{137}Cs	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sediment- ^{90}Sr						•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•
Sediment- tritium	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sediment- uranium	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Sampling	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995-2007
Soil- gross alpha	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•
Soil- gross beta	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•
Soil- gross gamma													•	•	•	•	•				•	•	•	•	•
Soil- ^{238}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Soil- ^{239}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Soil- ^{241}Am	•																				•	•	•	•	•
Soil- ^{137}Cs	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Soil- ^{90}Sr						•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•
Soil- tritium	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Soil- total uranium		•			•	•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•
Surface water- alpha	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•					•	•	•	•
Surface water- beta	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•					•	•	•	•
Surface water- gamma													•	•	•						•	•	•	•	•
Surface water- ^{241}Am			•	•	•	•	•					•	•	•	•							•	•	•	•
Surface water- ^{238}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Surface water- ^{239}Pu	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Surface water- ^{137}Cs	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Surface water- ^{90}Sr						•				•	•	•	•	•	•						•	•	•	•	•
Surface water- tritium	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Surface water- uranium	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Surface water- beryllium	•	•																							
Surface water- cadmium	•	•																							
Surface water- lead	•	•																							
Surface water- mercury	•	•																							
Surface water- chemical	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vegetables- ^{238}Pu					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vegetables- ^{239}Pu					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vegetables- ^{137}Cs												•	•	•	•	•	•	•		•	•	•	•	•	•
Vegetables- ^{90}Sr									•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
Vegetables- uranium					•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vegetables- tritium					•	•	•	•	•										•	•	•	•	•	•	•
Vegetation- plutonium			•																						
Water (potable)- Rad.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Water (potable)- Chem.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Soild Waste Disposal		•																							
TLD's (onsite/offsite)	58	59	65	22	44	48	50	55	50	61	152	155	155	155	155	155	155	155	155	151	151	151	166	166	97 - 150+
Radiation Dose Ass.			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Special Studies	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Honey bees- Rad.	•	•	•									•	•	•	•	•	•	•	•	•	•	•	•	•	•
Unplanned releases				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Study #2: Radioactivity in Los Alamos and Pueblo Creek (1947-1949) - Samples were collected at various points along streams inside Los Alamos and Pueblo Canyons and analyzed for plutonium, uranium, polonium, and gross beta/gamma (Schnap and Tribby, 1948).

Four liquid discharge pipes that serviced Technical Area 2 (TA-2) and two liquid discharge pipes that serviced Technical Area 3 (TA-3) all discharged liquid wastes to separate seepage pit systems. These pits were designed to hold the liquids for seepage to underlying soils and evaporation, but are reported to have clogged on occasion, resulting in release of waste liquids to Pueblo Canyon.

Radioactive contamination monitoring within the surrounding canyons was performed to determine the impact from these early waterborne releases. Documented in reports as early as 1945, direct alpha, beta, and gamma radiation surveys were conducted by LANL personnel along the discharge drainage areas immediately down-gradient of the discharge pipes (i.e., canyon walls) and throughout drainage areas of the canyons. Water samples from each discharge pipe were collected and analyzed for plutonium, uranium, mixed fission products, fluorine, and toxic metals. Plutonium was measured in effluent waters released from TA-1 and TA-2 operations, and ranged up to 1% by weight (Tribby, 1947). During these early years, TA-3 did not handle plutonium compounds and concentrations usually averaged around 0.01 dpm L^{-1}. Seepage pits were also surveyed for radioactive contamination and found to be highly radioactive.

Results for selected soil samples collected around TA-1 and TA-2 seepage pits in 1947 revealed levels of plutonium up to 50 dpm g^{-1}. Polonium levels around TA-3 seepage pits were measured up to 3,000 dpm g^{-1}. In 1947, Tribby reported that plutonium levels on canyon walls and canyon beds near discharge points were quite high, and that concentration levels dropped off rapidly 100 ft and beyond release points.

Waterborne radioactive waste was released without treatment to Acid Canyon from 1944 to 1951, when a treatment plant at TA-45 became operational. From 1951 to mid-1953, the TA-45 waste treatment facility only treated liquid waste from TA-1. Beginning in the second half of 1953, wastes from TA-1 and TA-3 were treated at TA-45.

From 1953 through the 1960s, wastes from TA-1 and TA-3 were treated at the TA-45 Waste Treatment Facility and discharged to Pueblo Canyon. Ferric sulfate and lime were added to incoming wastes to form a precipitate of ferric hydroxide, which contained most of the plutonium that would, in turn, settle to the bottom of the waste storage tanks. Also during this period, liquid wastes from the DP West production area were treated at the DPW Area Waste treatment Plant and released to Los Alamos Canyon.

Study #3: Radioactivity in Los Alamos, Pueblo, and Bayo Canyons (1957–1958) – During 1957 and 1958, the U.S. Geological Survey collected water samples from streams located in Los Alamos and Pueblo Canyons. These locations included: 1) Pueblo Canyon at Otowi Ruins, 2) Los Alamos canyon at Bridge, 3) Los Alamos Canyon at Totavi, and 4) Bayo Canyon(Abrahams, 1958).

Study #4: Radioactivity in Rio Grande (1957–1958) – During 1957, the U.S. Geological Survey collected water samples from the Rio Grande. Monthly samples were analyzed for gross alpha, plutonium, and uranium, and gross beta. Samples were collected at the Embudo, Chama, Otowi, and Cochiti stations (Abrahams, 1958)

Study #5: Radioactivity, Chromate, and Zinc in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons (1969-1970) – During 1969 and 1970, LANL (H-8 Group) reported measured radioactivity levels for surface water samples collected from streams located in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons. Monthly and quarterly samples were analyzed for gross alpha, gross beta, plutonium-238, plutonium-239, americium, strontium, cesium, tritium, and uranium (Kennedy, 1971). A limited number of samples were also analyzed for hexavalent chromium and zinc.

Study #6: Plutonium in Pueblo and Acid Canyons (1970) – Sediment samples collected along Pueblo Canyon drainage basin showed a decreasing trend in plutonium levels as a function of distance from LANL discharge points (Hanson, 1973). Based on a limited number of samples, the following plutonium concentrations in sediment were reported:

- 27 pCi g^{-1} in lower Acid Canyon
- 4.6 pCi g^{-1} in Pueblo Canyon 1 mi below Acid Canyon
- 1.1 pCi g^{-1} in Pueblo Canyon 2 mi below Acid Canyon
- 1. pCi g^{-1} in Pueblo Canyon 0.1 mi above the junction with Los Alamos Canyon

Detailed survey results are reported in document LA-4561, and will be reviewed by the project team for the next version of this report. The reported estimate of plutonium releases from TA-1 and TA-45 to Pueblo Canyon from 1944 to 1964 is 170 mCi (Hanson, 1973). Plutonium measured in surface water samples collected in Acid and Pueblo Canyons averaged 20 pCi L^{-1} during this period, compared to 1.5 and 0.22 pCi L^{-1} in Mortandad and Los Alamos Canyons, respectively.

Study #7: Radioactivity in Bayo Canyon (1977) – In 1977, LANL collected surface water samples from Bayo Canyon. Radiochemical analysis of samples showed that residual ^{90}Sr concentrations in soil averaged for the time period were 1.4 pCi g^{-1} (LASL, 1978a).

Historical Soil Monitoring Data

Samples of available soil monitoring data collected in areas of concern described in the above section are presented below.

Study #1: Radioactivity in Los Alamos Canyon (1947) – Soil samples were collected along the canyon walls and at various locations along the canyon floor and analyzed for plutonium, polonium, uranium, other unspecified radionuclides, fluorine, and unspecified toxic metals (Tribby, 1947). The available copy of this memo report reviewed by the project team appears to contain limited data for these surveys, and/or is missing some of the sample results, and warrants further research for data of this time period.

Study #2: Radioactivity in Los Alamos and Pueblo Creek (1947) – Soil samples were collected at various points along streams inside Los Alamos and Pueblo Canyons and analyzed for plutonium, uranium, polonium, and gross beta/gamma (Schnap and Tribby, 1948).

Study #3: Radioactivity in Bayo Canyon (1973-1977) – In 1977, LANL collected soil samples from Bayo Canyon and analyzed them for radioactivity. Study results showed that residual ^{90}Sr concentrations in soil averaged 1.4 pCi g^{-1} (LASL, 1978a). Previously reported surveys cited in this report include measured soil concentration results for gross alpha, gross beta, cesium, plutonium, and uranium.

Historical External Radiation Monitoring Data

Samples of available external radiation monitoring data collected in areas of concern described in the above section are presented below.

Study #1: Direct Radiation Readings in Los Alamos Canyon (1947) – Direct radiation measurements with a Geiger Mueller survey m were collected throughout Los Alamos Canyon, and were some of the first reported measurements of this type. The discharge line, the canyon walls directly below the wastewater discharge point, and the canyon floor exhibited the highest readings, up to 20,000 counts per minute of alpha radioactivity (Tribby, 1947).

Study #2: Radiation Levels in Mortandad Canyon (1952) – In 1952, LANL scientists conducted a series of radiation surveys throughout Mortandad Canyon following an accidental release of 2000 to 3000

gallons of "hot water" from waste storage tanks located at the TA-35 Liquid Waste Treatment Plant. Survey results indicated that migration of measurable radioactive contamination had occurred several mi downstream in the canyon. Reported radiation dose rate readings ranged from 0.5 milliroentgens (mR) per hour at a distance of three mi to 300 mR h^{-1} at the TA-35 perimeter fence (Aeby, 1952). The report also discussed a planned release to the canyon of 50,000 gallons of radioactive liquid waste with a concentration of 1.5 mCi L^{-1}, significantly above the tolerance limit. Specific isotopes were not stated in the memo report. Based on other information obtained about operations at the TA-35 for this time period, though, the released waste most likely contained ^{140}Ba, ^{140}La, trace amounts of ^{89}Sr ^{90}Sr, and other radionuclides.

Study #3: Radioactivity in Bayo Canyon (1973-1977) – Direct radiation measurements throughout Bayo canyon were taken with ion chambers and germanium detectors (LASL, 1978a).

Historical Ambient Air Monitoring Data

Samples of available ambient air monitoring data (including meteorological) collected in areas of concern described in the above section are presented below.

Study #1: LANL Meteorological Data (1956 to 1971) – Measured wind, temperature, pressure, humidity, and precipitation collected at various locations throughout Los Alamos and surrounding areas were presented (LANL, 1975).

Study #2: Beta/Gamma Concentrations at LANL (1961) – Airborne radioactive particulate samples collected on filter paper were reported for an air sampler located on the roof of the Administration Building SM-43. Air samples were collected every 24 h and 72 h over weekends (LASL, 1961). The report contains sampling results for the first quarter, 1961.

Historical Groundwater/Water Supplies Monitoring Data

Samples of available groundwater monitoring data collected in areas of concern described in the above section are presented below.

Study #1: Radioactivity in Los Alamos, Pueblo, and Guaje Canyons (1957-1958) – In 1958, groundwater, water supplies, and springs located in the Los Alamos area and in Los Alamos, Pueblo, and Guaje Canyons were sampled by the U.S. Geological Survey. The samples were analyzed for pH, gross

alpha, plutonium, uranium, gross beta, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO_3, and conductivity (Abrahams, 1958).

Study # 2: Radioactivity and Other Constituents in U.S. Geological Water Samples (1960) – In 1960, groundwater and water supplies were sampled by the U.S. Geological Survey. The samples were analyzed for pH, gross alpha, plutonium, uranium, gross beta, total hardness, calcium, magnesium, sodium, chloride, fluoride, total solids, and conductivity (USGS, 1961).

Study #3: Chromate and Zink in Sandia Canyon (1969-1970) – During 1969 and 1970, LANL (H-8 Group) reported hexavalent chromium and zinc levels in groundwater samples collected from monitoring wells located in Sandia Canyon (Kennedy, 1971).

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Chapter 15: Development of Residential Areas Around LANL

For a radionuclide or chemical that was used at LANL to have posed a health hazard to members of the public, each of the following elements must have existed:

- A **contaminant source** that released the material into the environment,
- A **transport medium** that carried the contaminant off site to a location where exposure took place (the most common media being air and water), and
- An **exposure route** through which the contaminant entered an individual's body to produce adverse health effects. Examples of exposure routes include inhalation, ingestion, and immersion in airborne contamination.

Evaluation of off-site exposures from activities at LANL technical areas will require documentation of the development of nearby residential areas over time. While it was initially thought that the 31 houses commandeered from the Los Alamos Ranch School and Anchor Ranch would provide sufficient housing for the projected staff of 30 scientists and their families (Martin, 2000), it soon became clear that the challenge of providing housing for LANL staff had been severely underestimated. The scarcity of housing in Los Alamos was problematic during World War II, and remained so for years to follow. Hiring at LANL was severely restricted at times because there was nowhere for new employees to live. This pressure to provide housing and the limited availability of suitable land in the region of finger-like mesas and canyons led to the development of housing that, in some cases, was much closer to operational areas than has become customary for government facilities that undertake nuclear material and high explosive processing and/or reactor or high-energy particle accelerator operations.

Development of Housing Areas in Los Alamos

In response to the atomic weapons race of WWII, in 1943, Los Alamos, New Mexico, home of the Los Alamos Ranch School, was chosen as the location of key Manhattan Project operations. Initially, the 54 buildings of the private boys' school (27 of which were houses) were thought to be satisfactory for housing the projected staff of scientists and their families (Martin, 2000, Hunner, 2004). Soon after the project began, though, the need for further housing became inevitable, and construction of the Sundt apartments began to the west and north of the Ranch School buildings (Martin, 2000). The population of

Los Alamos continued to grow during 1944 and 1945, and, in response, several temporary housing developments were erected in the vicinity of the original town site.

The LAHDRA Project Reference Map provided with this report shows the different residential areas of Los Alamos, and depicts the periods of their development, the periods they remained in use, and the proximity of the different housing areas to operational areas of potential interest. The original Technical Area (TA-1) and wartime and early postwar housing in Los Alamos are shown in Figure 15-1, which is also included as an inset map in the Project Reference Map.

With the success of the Trinity Test in July, 1945 and the ultimate ending of WWII in the September that followed, the original mission of the Manhattan Project was accomplished (Martin, 2000). Many scientists and their families, unsure of the future of LANL, returned to pre-war careers and lives in different locations. In 1946, over 1,000 residents left the town of Los Alamos (Hunner, 2004). The temporary housing constructed during the war was deteriorating, and, in 1946, the laboratory began developing the first permanent housing in the Western Area of Los Alamos to encourage the residents to remain in the town (Martin, 2000, Hunner, 2004). After realizing that LANL was to become a permanent location for research, turnover slowed and hiring increased (LASL, 1956). Expansion of the Western Area and town site continued through the late 1940s in response to overcrowding. The Los Alamos population grew from approximately 7,000 people in 1947 to over 8,500 people in 1949 (Hunner, 2004). The main areas of residential development in Los Alamos from 1946 through 2000 are shown in Figure 15-2.

As a result of President Truman's decision to further research hydrogen bomb development in 1949, significant amounts of money flowed into LANL to support new laboratory research and handle the arrival of new personnel (Hunner, 2004). The population grew from slightly over 8,500 in 1949 to 12,800 by 1952 (Hunner, 2004). Residential areas began to expand northward into the North Community, and expansion continued into the early 1950s. Temporary housing constructed during the war years began to be replaced with permanent housing in the mid 1950s (LASL, 1956, Martin, 2000). The LANL facilities began to be moved from the Ashley Pond area to the South Mesa. To support the necessary construction crews and their families, in 1949, White Rock construction camp was erected on a level plain near the rim of White Rock Canyon and Totavi trailer camp was erected on San Ildefonso Pueblo land to the east of Los Alamos along New Mexico Highway 502 (Martin, 1998, 2000, Hunner, 2004). Both camps were short-lived, however, with White Rock nearly closing by 1953 and entirely shutting down in 1957, and Totavi shutting down in 1953 (Martin, 1998, 2000).

The government maintained ownership of all property in Los Alamos until 1958, when Barranca Mesa was opened for private ownership on the mesa north of Bayo Canyon (Martin, 2000). Development continued on Barranca Mesa through the mid-1960s, and continued growth forced expansion onto the narrow neck of the mesa in the late 1970s and early 1980s (Martin, 2000). The area of White Rock re-opened to house low-income families in 1962, and growth continued throughout the 1960s and 1970s (Martin, 2000). To accommodate the seemingly continuous shortage of housing, construction on the North Mesa began for both subdivisions and mobile home parks in 1977 (Martin, 2000).

Following several years of rapid development, Los Alamos experienced relatively slow growth throughout the 1980s (Martin, 2000). New construction returned in the mid-1990s with the development of Ponderosa Estates near the Guaje Pines Cemetery in the northern part of the town. In 2000, the devastating Cerro Grande Fire destroyed over 400 homes in the Western Area and North Community (Martin, 2000). Rebuilding the burned areas continues today, and new developments, such as the Quemazon Community in the northwest area of town, are being erected (Kron, personal communication, 2005).

Locations of Interest When Considering Historical Operations

Based on reviews of historical documents performed to date, the following locations are among the sites where historical operations took place that appear to warrant evaluation in terms of potential off-site releases or health effects:

- D-Building at the original technical area (TA-1)
- DP West (TA-21; with released primarily from Building 12 stacks)
- DP East (TA-21; with released primarily from Buildings 152 and 153)
- Omega Site Reactors (TA-2)
- TA-3, the current main Technical Area
- The LAMPF (now LANSCE) accelerator complex
- High explosives manufacturing areas (example used is S-Site, TA-16)
- High Explosives firing sites (example used is R-Site, TA-15)
- Bayo Canyon firing site (TA-10, site of radioactive lanthanum test shots)

For evaluation of potential health effects from historical releases, each of these locations should be evaluated with regard to its relationship to Los Alamos housing areas and public facilities that were occupied during time periods that correspond to periods when operations of interest were also active. Philomena's restaurant, which began operating in the late 1970s, has been an area of interest due to its proximity to the LAMPF (now LANSCE) facility. Although not a Los Alamos housing area, San Ildefonso Pueblo land is also considered important to evaluate due to its close proximity to LANL operations. The housing areas and public facilities that will be most important for a given location of operations depend on a number of factors, including:

- The distance from the contaminant source to the housing area,
- The direction from the contaminant source to the housing area, and
- The prevalence of winds from the contaminant source towards the housing area.

Detailed dose assessment typically utilizes air dispersion modeling based on actual locations of release points and potentially exposed people, using meteorological data that reflect any diurnal or seasonal variations in air flow patterns. As preliminary indicators of residential areas that may be of concern, however, it is useful to examine distance, direction, and wind prevalence for relevant source-receptor combinations.

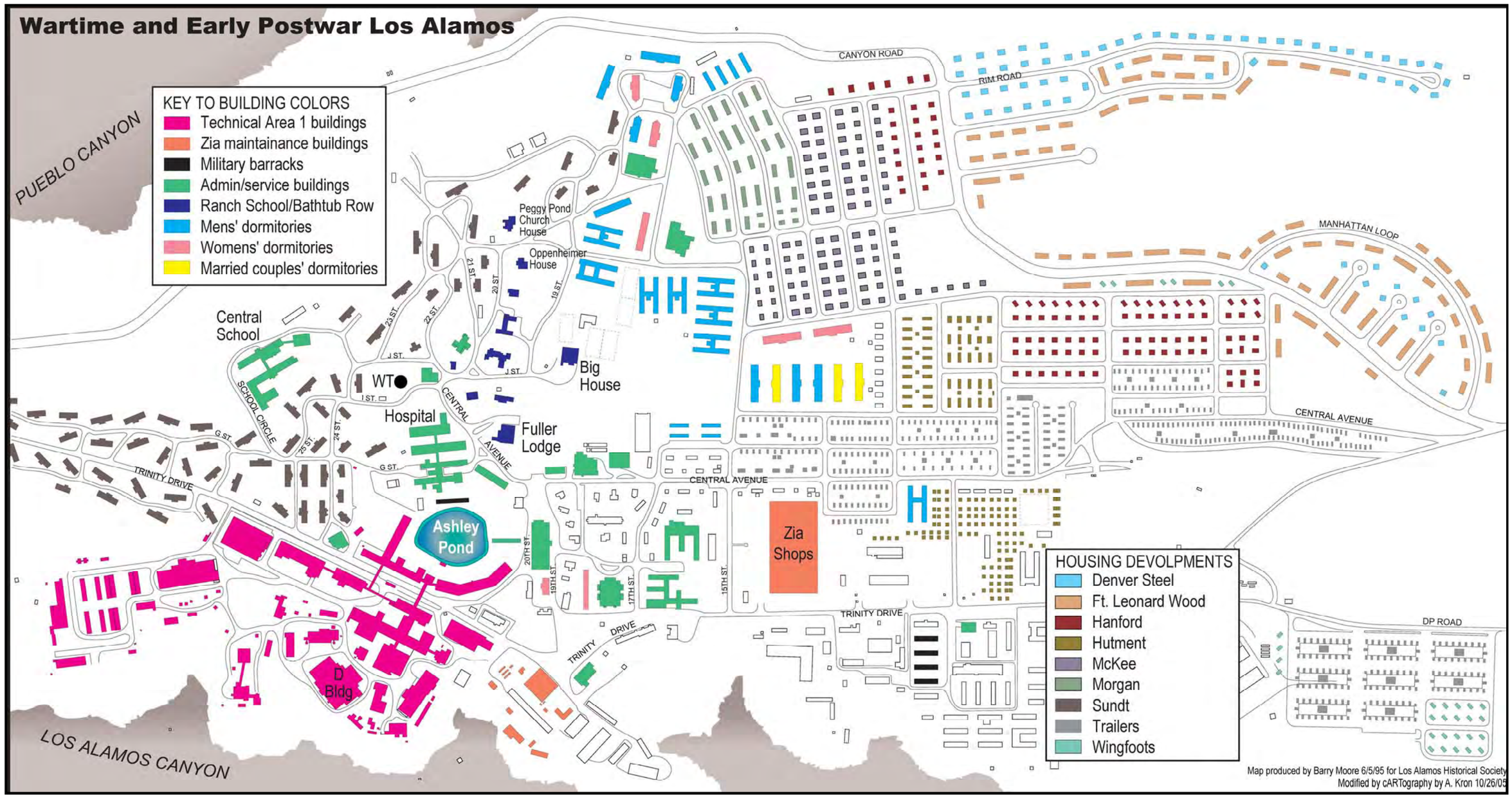
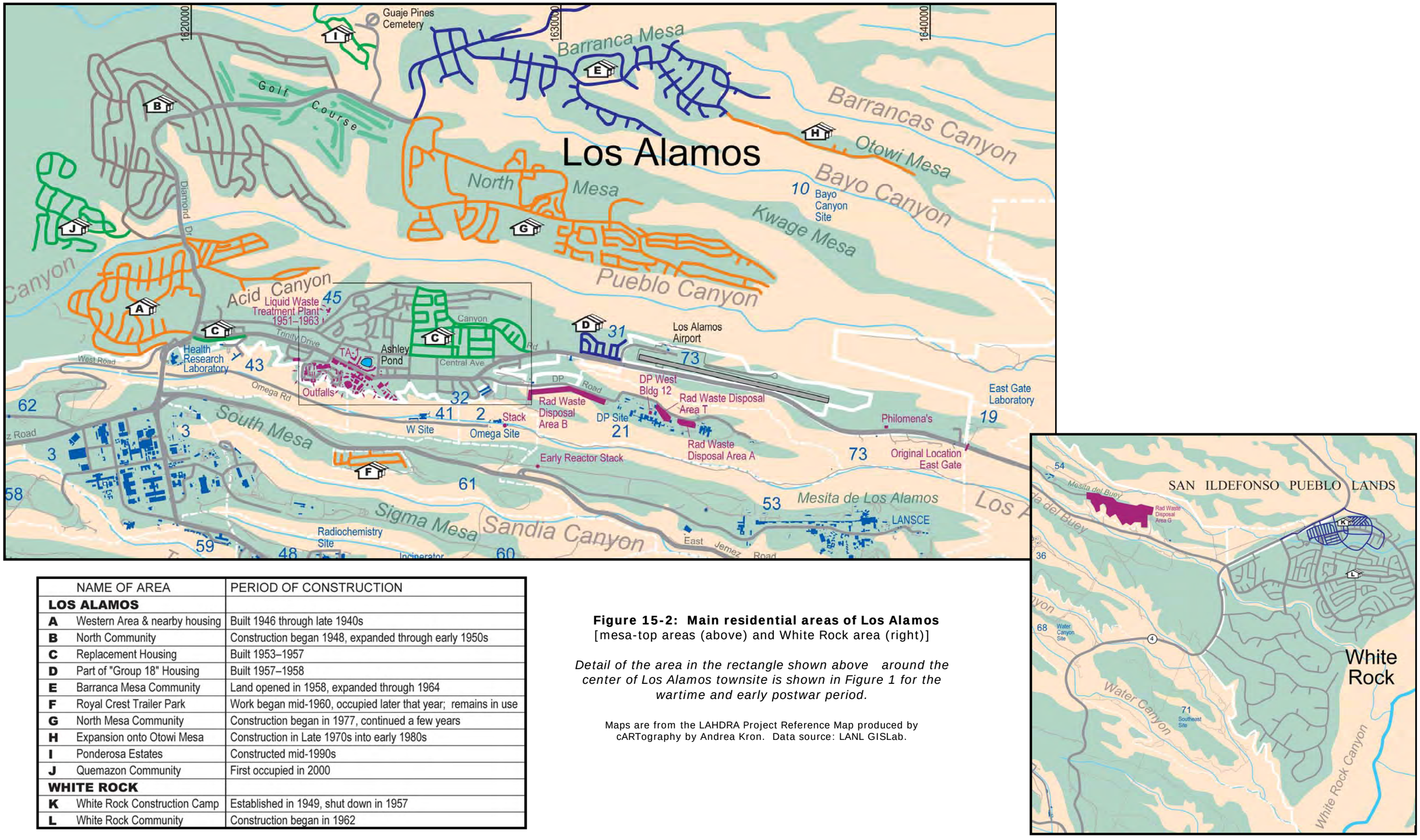


Figure 15-1: The original Los Alamos Technical Area (lower left corner) and wartime and early postwar housing

Back of Figure 15-1, 11×17



	NAME OF AREA	PERIOD OF CONSTRUCTION
LOS ALAMOS		
A	Western Area & nearby housing	Built 1946 through late 1940s
B	North Community	Construction began 1948, expanded through early 1950s
C	Replacement Housing	Built 1953–1957
D	Part of "Group 18" Housing	Built 1957–1958
E	Barranca Mesa Community	Land opened in 1958, expanded through 1964
F	Royal Crest Trailer Park	Work began mid-1960, occupied later that year; remains in use
G	North Mesa Community	Construction began in 1977, continued a few years
H	Expansion onto Otowi Mesa	Construction in Late 1970s into early 1980s
I	Ponderosa Estates	Constructed mid-1990s
J	Quemazon Community	First occupied in 2000
WHITE ROCK		
K	White Rock Construction Camp	Established in 1949, shut down in 1957
L	White Rock Community	Construction began in 1962

Figure 15-2: Main residential areas of Los Alamos
[mesa-top areas (above) and White Rock area (right)]

Detail of the area in the rectangle shown above around the center of Los Alamos townsite is shown in Figure 1 for the wartime and early postwar period.

Maps are from the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.

Back of Fig 15-2, 11×17

Locations of Interest When Considering Historical Operations

Based on reviews of historical documents performed to date, the following locations are among the sites where historical operations took place that appear to warrant evaluation in terms of potential off-site releases or health effects:

- D-Building at the original technical area (TA-1)
- DP West (TA-21; with released primarily from Building 12 stacks)
- DP East (TA-21; with released primarily from Buildings 152 and 153)
- Omega Site Reactors (TA-2)
- TA-3, the current main Technical Area
- The LAMPF (now LANSCE) accelerator complex
- High explosives manufacturing areas (example used is S-Site, TA-16)
- High Explosives firing sites (example used is R-Site, TA-15)
- Bayo Canyon firing site (TA-10, site of radioactive lanthanum test shots)

For evaluation of potential health effects from historical releases, each of these locations should be evaluated with regard to its relationship to Los Alamos housing areas and public facilities that were occupied during time periods that correspond to periods when operations of interest were also active. Philomena's restaurant, which began operating in the late 1970s, has been an area of interest due to its proximity to the LAMPF (now LANSCE) facility. Although not a Los Alamos housing area, San Ildefonso Pueblo land is also considered important to evaluate due to its close proximity to LANL operations. The housing areas and public facilities that will be most important for a given location of operations depend on a number of factors, including:

- The distance from the contaminant source to the housing area,
- The direction from the contaminant source to the housing area, and
- The prevalence of winds from the contaminant source towards the housing area.

Detailed dose assessment typically utilizes air dispersion modeling based on actual locations of release points and potentially exposed people, using meteorological data that reflect any diurnal or seasonal

variations in air flow patterns. As preliminary indicators of residential areas that may be of concern, however, it is useful to examine distance, direction, and wind prevalence for relevant source-receptor combinations.

A 16-sector wind direction frequency distribution based on LANL measurements over a ten-year period was used to determine the prevalence of winds from release points of interest towards housing areas and public facilities. That wind frequency distribution is shown in Table 15-1. This table reflects a wide variation in wind direction when all data are included. By instead examining data from specific times of the day, recognizable diurnal air flow patterns emerge. As observed in many mountainous areas, air flow is typically up-valley during the day (as solar heating causes air to rise) and down-valley at night (as cooling air drains to lower elevations). These patterns are not seen in the general wind direction data shown in Table 15-1, but they are important to consider when evaluating releases that may have only occurred during daylight hours versus those that may have occurred around the clock.

Tables 15-2 through 15-10 summarize information relevant to evaluating the potential importance of public areas in terms of releases from the identified locations of interest. In instances where the operational location of interest was large or had numerous release points, the distance was measured from the middle of the complex, which was necessary with the current main technical area (TA-3) and LAMPF (now LANSCE). Distance was measured in increments of 0.25 mi, and always rounded down to the closer distance if a point fell between two distances. In most cases, the distance between the location of interest and the various public areas is presented as a range from the closest to the farthest possible points. Direction, however, was determined by using the public area closest to the location of interest.

Housing areas irrelevant to operations of a particular facility (that is, they did not exist when that facility was operational) are shown in gray instead of black in Tables 15-2 through 15-10 to indicate that residential exposures were not possible.

Because of its close proximity to LANL operations, San Ildefonso Pueblo land is also considered an area of interest. The vast amount of land there makes it necessary to determine which of the land areas were historically used for residential purposes. Traditionally, Pueblo members lived near their central plaza and had fields that they tended outside of this area (ChemRisk Inc., 2006). According to a 1953 USGS map of Espanola, New Mexico, the concentration of San Ildefonso Pueblo people nearest to Los Alamos was north of the current Highway 502 and east of the Rio Grande (ChemRisk Inc., 2006).

Table 15-1: Wind direction frequency distribution based on 10 years of LANL data

Sector	Wind from	Wind towards	Percentage
1	N	S	3.4233
2	NNE	SSW	3.6218
3	NE	SW	3.3293
4	ENE	WSW	3.1224
5	E	W	3.4616
6	ESE	WNW	3.3936
7	SE	NW	3.718
8	SSE	NNW	6.0108
9	S	N	8.8439
10	SSW	NNE	8.2649
11	SW	NE	7.7308
12	WSW	ENE	8.1937
13	W	E	11.4148
14	WNW	ESE	11.9399
15	NW	SE	9.2887
16	NNW	SSE	4.2424

Table 15-2: D-Building at the Original Technical Area (operational from 1943 to 1953)

Public Area*	Period Occupied	Distance from D-Building (mi)	Direction from D-Building	Winds in this direction (%)
Wartime Housing	1943-1945	0.1-0.75	NW	3.7
Early Postwar Housing	1946-1960s	0.25-1	NE	7.7
Western Area	1946-present	0.25-1.5	WNW	3.4
North Community	1948-present	0.75-2	NW	3.7
Replacement Housing	1953-present	0.25-0.75	NE	7.7
Group 18 Homes by Airport	1957-present	0.75-1.25	ENE	8.2
Barranca Mesa	1958-present	1.5-2.5	NNE	8.3
Royal Crest Trailer Park	1960-present	0.75	SE	9.3
North Mesa	1977-present	0.75-2.25	NNE	8.3
Otowi Mesa Expansion	late 1970s-present	2.25-3	NE	7.7
Ponderosa Estates	Mid 1990s-present	1.5-2	N	8.8
East Gate / Philomena's	Late 1970s-present	2.25	E	11.4
Totavi Camp	1949-1953	7	E	11.4
White Rock Camp	1949-1953 (1957)	6.25-7	SE	9.3
White Rock Community	1962-present	5.75-8	SE	9.3
San Ildefonso Pueblo Lands	1598-present	10.25	E	11.4

*Public areas in gray were not in existence during site operation period.

Table 15-3: DP West Site at TA-21 (operational from 1945 to 1973)

Public Area*	Period Occupied	Distance from DP West (mi)	Direction from DP West	Winds in this direction (%)
Wartime Housing	1943-1945	0.75-2	WNW	3.4
Early Postwar Housing	1946-1960s	0.5-2.5	NW	3.7
Western Area	1946-present	2.25-2.75	WNW	3.4
North Community	1948-present	1.75-3.25	NW	3.7
Replacement Housing	1953-present	0.5-2.25	WNW	3.4
Group 18 Homes by Airport	1957-present	0.25-0.5	NNW	6.0
Barranca Mesa	1958-present	1.5-2.25	N	8.8
Royal Crest Trailer Park	1960-present	0.75	SW	3.3
North Mesa	1977-present	0.75-1.75	NNW	6.0
Otowi Mesa Expansion	late 1970s-present	1.5-1.75	NE	7.7
Ponderosa Estates	Mid 1990s-present	2-2.5	NNW	6.0
East Gate / Philomena's	Late 1970s-present	1.25	E	11.4
Totavi Camp	1949-1953	5.5	E	11.4
White Rock Camp	1949-1953 (1957)	5.25	SE	9.3
White Rock Community	1962-present	5-7	SE	9.3
San Ildefonso Pueblo Lands	1598-present	9	ENE	8.2

*Public areas in gray were not in existence during site operation period.

Table 15-4: DP East Site at TA-21 (operational from 1945 to 1970)

Public Area*	Period Occupied	Distance from DP East (mi)	Direction from DP East	Winds in this direction (%)
Wartime Housing	1943-1945	1.25-2.25	WNW	3.4
Early Postwar Housing	1946-1960s	1-2.75	WNW	3.4
Western Area	1946-present	2.75-3.25	WNW	3.4
North Community	1948-present	2-3.75	NW	3.7
Replacement Housing	1953-present	1-2.75	WNW	3.4
Group 18 Homes by Airport	1957-present	0.5-0.75	NW	3.7
Barranca Mesa	1958-present	1.5-2.25	NNW	6.0
Royal Crest Trailer Park	1960-present	1	WSW	3.1
North Mesa	1977-present	0.75-2.25	NNW	6.0
Otowi Mesa Expansion	late 1970s-present	1.5	NNE	8.3
Ponderosa Estates	Mid 1990s-present	2.25-3	NNW	6.0
East Gate / Philomena's	Late 1970s-present	0.75	E	11.4
Totavi Camp	1949-1953	5	E	11.4
White Rock Camp	1949-1953 (1957)	5	SE	9.3
White Rock Community	1962-present	4.5-7	SE	9.3
San Ildefonso Pueblo Lands	1598-present	8.25	ENE	8.2

*Public areas in gray were not in existence during site operation period.

Table 15-5: Omega Site Reactors at TA-2 (operational from 1943 To 1992)

Public Area*	Period Occupied	Distance from Omega Site (mi)	Direction from Omega Site	Winds in this direction (%)
Wartime Housing	1943-1945	0.25-1.25	WNW	3.4
Early Postwar Housing	1946-1960s	0.25-1.75	N	8.8
Western Area	1946-present	1.5-2.25	WNW	3.4
North Community	1948-present	1.25-2.25	NW	3.7
Replacement Housing	1953-present	0.25-0.75	N	8.8
Group 18 Homes by Airport	1957-present	0.5-0.75	NE	7.7
Barranca Mesa	1958-present	1.75-2.25	NNE	8.3
Royal Crest Trailer Park	1960-present	0.25	S	3.4
North Mesa	1977-present	1-1.5	N	8.8
Otowi Mesa Expansion	late 1970s-present	2-2.5	NE	7.7
Ponderosa Estates	Mid 1990s-present	1.75-2.25	NNW	6.0
East Gate / Philomena's	Late 1970s-present	1.75	E	11.4
Totavi Camp	1949-1953	6.25	E	11.4
White Rock Camp	1949-1953 (1957)	5.75	SE	9.3
White Rock Community	1962-present	5.25-7.25	SE	9.3
San Ildefonso Pueblo Lands	1598-present	8.5	ENE	8.2

*Public areas in gray were not in existence during site operation period.

Table 15-6: TA-3, the current main technical area (operational from 1953 to present)

Public Area*	Period Occupied	Distance from TA-3 (mi)	Direction from TA-3	Winds in this direction (%)
Wartime Housing	1943-1945	0.75-1.75	NE	7.7
Early Postwar Housing	1946-1960s	1-2	NE	7.7
Western Area	1946-present	0.5-1	N	8.8
North Community	1948-present	1.25-2.25	N	8.8
Replacement Housing	1953-present	0.5-2	NE	7.7
Group 18 Homes by Airport	1957-present	2-2.5	ENE	8.2
Barranca Mesa	1958-present	2.25-3.5	NE	7.7
Royal Crest Trailer Park	1960-present	1.75	E	11.4
North Mesa	1977-present	1.75-3.25	NE	7.7
Otowi Mesa Expansion	late 1970s-present	3.5-4	NE	7.7
Ponderosa Estates	Mid 1990s-present	2-2.5	NNE	8.3
East Gate / Philomena's	Late 1970s-present	3.5	E	11.4
Totavi Camp	1949-1953	8	E	11.4
White Rock Camp	1949-1953 (1957)	7.25	SE	9.3
White Rock Community	1962-present	6.5-9	SE	9.3
San Ildefonso Pueblo Lands	1598-present	11.5	ENE	8.2

*Public areas in gray were not in existence during site operation period.

Note – Distance from TA-3 is measured from middle of complex.

Table 15-7: LAMPF (now LANSCE, operational from 1968 to present)

Public Area*	Period Occupied	Distance from LAMPF Building (mi)	Direction from LAMPF Building	Winds in this direction (%)
Wartime Housing	1943-1945	2-3	WNW	3.4
Early Postwar Housing	1946-1960s	1.75-3.5	WNW	3.4
Western Area	1946-present	3.25-4	WNW	3.4
North Community	1948-present	2.75-4.25	NW	3.7
Replacement Housing	1953-present	1.75-3.5	NW	3.7
Group 18 Homes by Airport	1957-present	1.25-1.75	NW	3.7
Barranca Mesa	1958-present	2.25-3.25	NNW	6.0
Royal Crest Trailer Park	1960-present	1.75	W	3.5
North Mesa	1977-present	1.25-3	NNW	6.0
Otowi Mesa Expansion	late 1970s-present	1.75-2.25	N	8.8
Ponderosa Estates	Mid 1990s-present	3.25-3.75	NW	3.7
East Gate / Philomena's	Late 1970s-present	0.5	NNE	8.3
Totavi Camp	1949-1953	4.5	E	11.4
White Rock Camp	1949-1953 (1957)	4	SE	9.3
White Rock Community	1962-present	3.75-6	SE	9.3
San Ildefonso Pueblo Lands	1598-present	8	ENE	8.2

*Public areas in gray were not in existence during site operation period.

Note – Distance from LANSCE building is measured from middle of complex.

Table 15-8: High Explosives Manufacturing Area – S-Site (TA-16, operational 1944 to present)

Public Area	Period Occupied	Distance from S-Site (mi)	Direction from S-Site Building	Winds in this direction (%)
Wartime Housing	1943-1945	3-3.75	NNE	8.3
Early Postwar Housing	1946-1960s	3.25-3.75	NNE	8.3
Western Area	1946-present	2.75-3.25	NNE	8.3
North Community	1948-present	3.5-4.25	N	8.8
Replacement Housing	1953-present	3-3.75	NNE	8.3
Group 18 Homes by Airport	1957-present	3.75-4	NE	7.7
Barranca Mesa	1958-present	4.75-5.25	NE	7.7
Royal Crest Trailer Park	1960-present	3	NE	7.7
North Mesa	1977-present	3.75-4.75	NNE	8.3
Otowi Mesa Expansion	late 1970s-present	5.25-5.75	NE	7.7
Ponderosa Estates	Mid 1990s-present	4.25-4.75	NNE	8.3
East Gate / Philomena's	Late 1970s-present	4.75	NE	7.7
Totavi Camp	1949-1953	9.5	ENE	8.2
White Rock Camp	1949-1953 (1957)	7-7.5	ESE	11.9
White Rock Community	1962-present	6.25-8	ESE	11.9
San Ildefonso Pueblo Lands	1598-present	12.5	ENE	8.2

Table 15-9: High Explosive Firing Site – R-Site (TA-15, operational from 1944 to present)

Public Area	Period Occupied	Distance from R-Site (mi)	Direction from R-Site Building	Daytime Winds in this direction (%)
Wartime Housing	1943-1945	2.5-3	N	8.8
Early Postwar Housing	1946-1960s	2.5-3.25	NNE	8.3
Western Area	1946-present	2.5-3.5	NNW	3.4
North Community	1948-present	3.25-4.25	N	8.8
Replacement Housing	1953-present	2.5-3	NNE	8.3
Group 18 Homes by Airport	1957-present	2.75-3	NNE	8.3
Barranca Mesa	1958-present	4-4.5	NNE	8.3
Royal Crest Trailer Park	1960-present	2	NNE	8.3
North Mesa	1977-present	3.25-3.75	N	8.8
Otowi Mesa Expansion	late 1970s-present	4.25-4.5	NNE	8.3
Ponderosa Estates	Mid 1990s-present	3.75-4.25	N	8.8
East Gate / Philomena's	Late 1970s-present	3.5	NE	7.7
Totavi Camp	1949-1953	7.5	ENE	8.2
White Rock Camp	1949-1953 (1957)	5.25-6.25	ESE	11.9
White Rock Community	1962-present	4.75-6.25	ESE	11.9
San Ildefonso Pueblo Lands	1598-present	10.5	ENE	8.2

Table 15-10: Bayo Canyon Firing Site (operational from 1944 to 1961)

Public Area*	Period Occupied	Distance from Bayo Canyon Firing Site (mi)	Direction from Bayo Canyon Firing Site	Winds in this direction (%)
Wartime Housing	1943-1945	2-3	WSW	3.1
Early Postwar Housing	1946-1960s	1.5-2.5	WSW	3.1
Western Area	1946-present	3.25-4	WSW	3.1
North Community	1948-present	2.5-4	W	3.5
Replacement Housing	1953-present	1.75-3.25	WSW	3.1
Group 18 Homes by Airport	1957-present	1.25-1.75	SW	3.3
Barranca Mesa	1958-present	0.75-2.25	NW	3.7
Royal Crest Trailer Park	1960-present	2.25	SW	3.3
North Mesa	1977-present	0.5-2.25	WSW	3.1
Otowi Mesa Expansion	late 1970s-present	0.25-0.75	N	8.8
Ponderosa Estates	Mid 1990s-present	2.5-3	WNW	3.4
East Gate / Philomena's	Late 1970s-present	1	S	3.4
Totavi Camp	1949-1953	5	ESE	11.9
White Rock Camp	1949-1953 (1957)	5.25	SSE	4.2
White Rock Community	1962-present	5-7.25	SSE	4.2
San Ildefonso Pueblo Lands	1598-present	8	E	11.4

*Public areas in gray were not in existence during site operation period.

Based on examination of the information presented in Tables 15-2 through 15-10 and information from historical documents reviewed by the LAHDRA project team, following are discussions of public areas that may be of importance in terms of evaluating releases from the historical operations of interest listed above.

a. D-Building at TA-1

D-Building at the original Technical Area was the site of plutonium processing during the war years. Specifically, D-Building housed plutonium purification and recovery, metal conversion, metallurgy, weapon component fabrication, and coating application. After DP West site became operational in late 1945, D-Building continued to house activities that involved plutonium, including chemical and metallurgical research and analysis, until a "new D-Building" was completed on South Mesa in the form of the CMR Building within Technical Area 3 (Coffinberry and Miner W.N (eds), 1961). D- Building was razed in 1953 (Alquist et al., 1977).

Due to D-Building's period of operation and proximity to the town site, Wartime Housing and Early Postwar Housing are public areas of interest in terms of historical releases from D- Building. Wartime housing ranged from 0.1-0.75 mi from D-Building, and the closest occupants were northwest of the D-

Building in the Sundt apartments. Wind blew in the northwest direction 3.7% of the time, as averaged over a ten year period. Early Postwar Housing ranged from 0.25 (Hanford Houses) to 1 mi (Denver Steel and Ft. Leonard Wood Houses) to the northeast of D-Building, with the wind blowing to the northeast 7.7% of the time. Figures 15-3, 15-4, and 15-5 show the original Technical Area with wartime housing in the form of Sundt apartments located nearby.

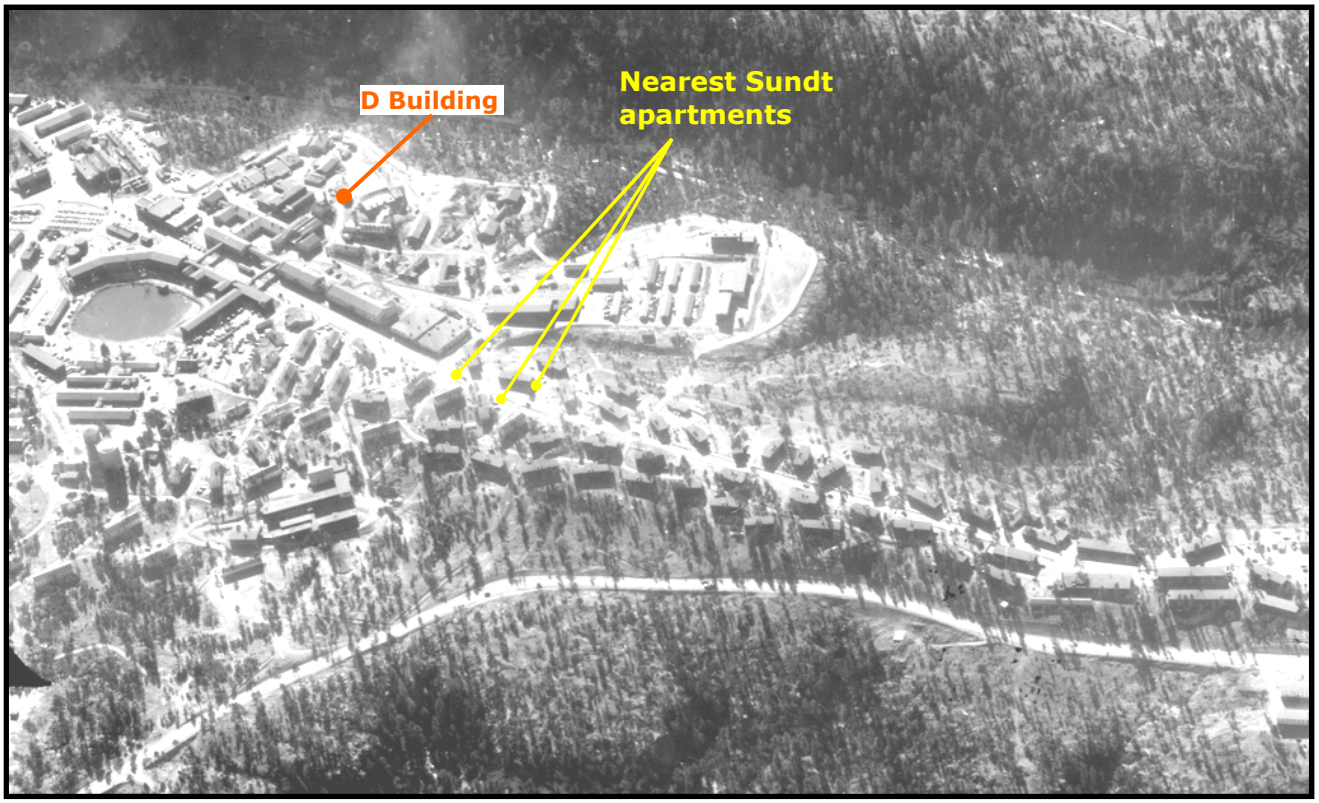


Figure 15-3: This November, 1946 aerial photograph, looking south, shows Sundt apartments west (to the right) of the Technical Area, on both sides of Trinity Drive, which crosses from the upper left to the lower right of the photo. *Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-1-3028).*

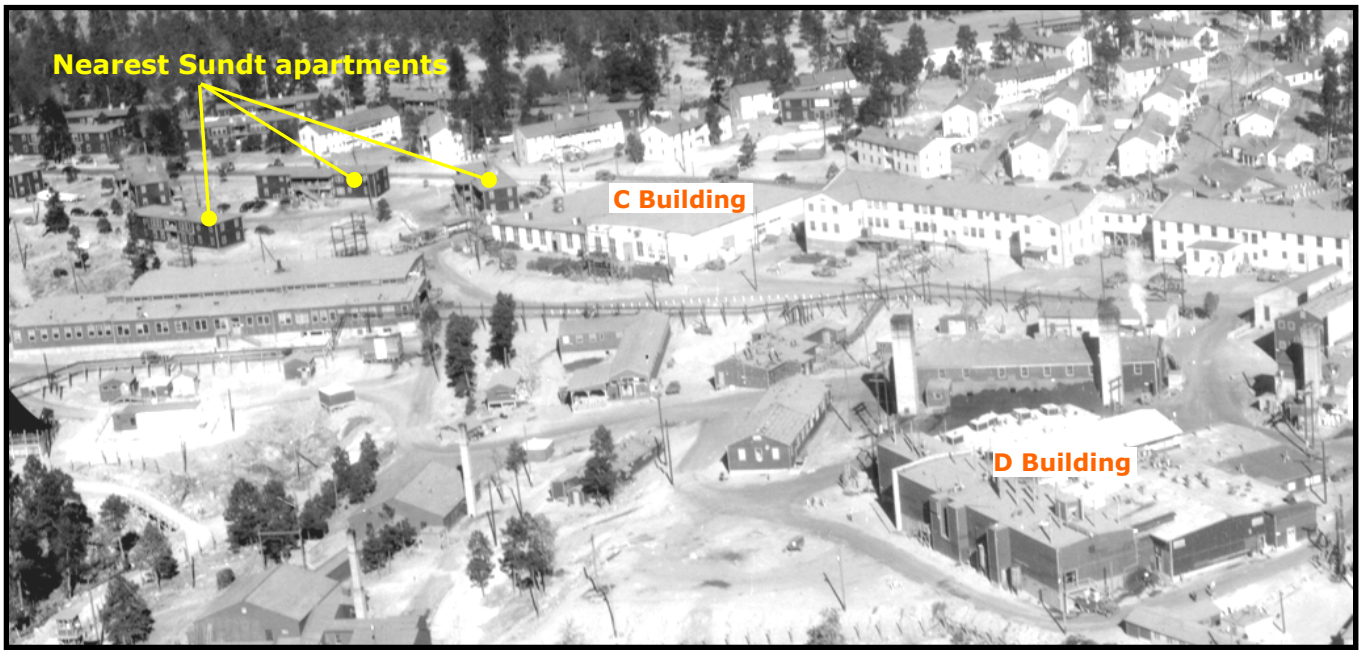


Figure 15-4: This December 4, 1946 aerial photograph, looking north, shows the Sundt apartments (dark buildings in upper left) immediately west and north of the Technical Area. The large building at the lower right is D-Building. The largest white Technical Area building nearest the Sundt Apartments (photo upper center) is C-Building, which housed shops and was the site of a January, 1945 fire that prompted of the need for replacement facilities for processing plutonium. *Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-1-3029).*

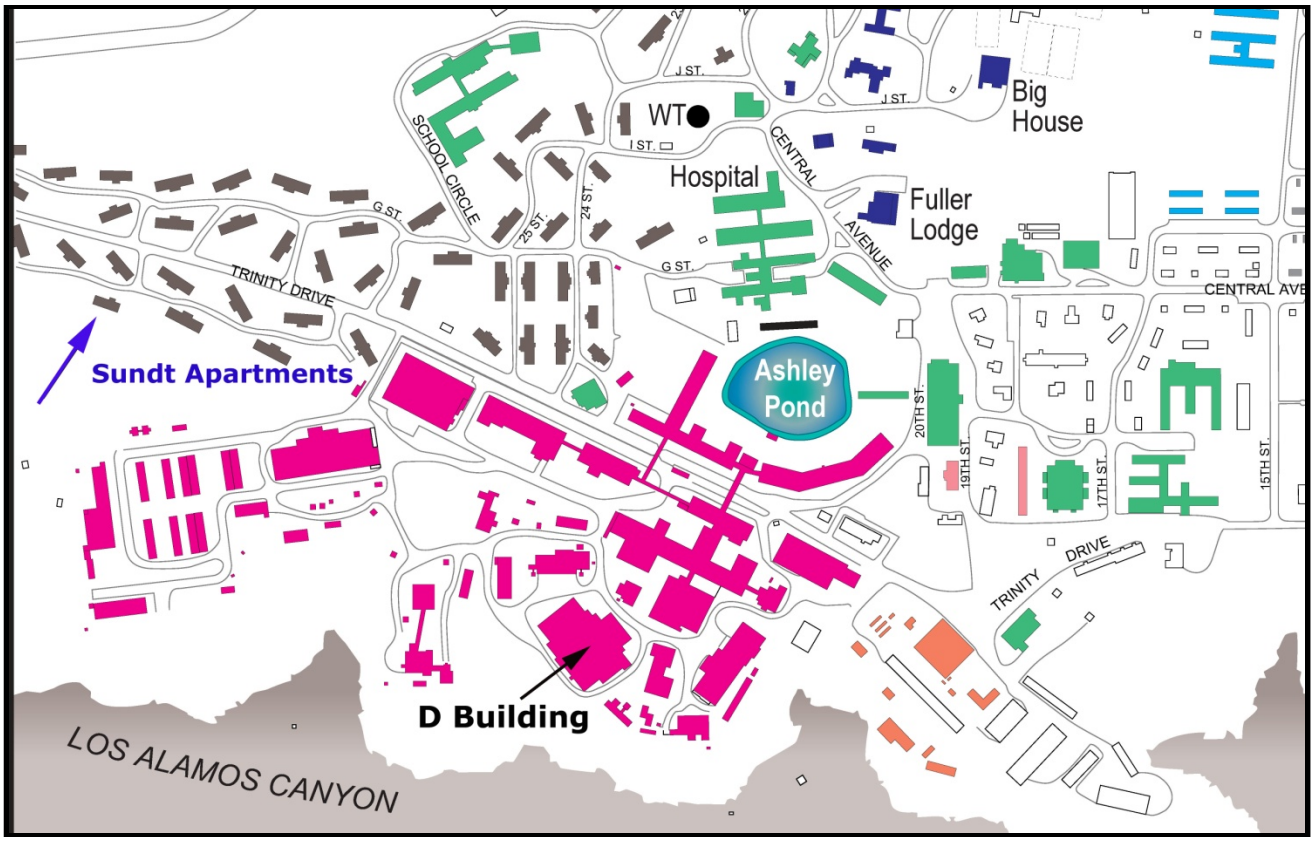


Figure 15-5: Location of D-Building within the original Technical Area relative to some Los Alamos wartime and early postwar housing. Sundt apartments are in the upper-left portion of the figure. The green buildings are administrative and service buildings, not residents. *From a map produced by Barry Moore for the Los Alamos Historical Society and modified by cARTography by Andrea Kron.*

b. DP West (TA-21; with Releases from Building 12 stacks)

In response to fire hazard and safety concerns, most plutonium processing operations moved to DP West in late 1945. Building 12 was the filter building for all of the plutonium processing buildings (2, 3, 4, and 5), and remained so until 1973. A public area of interest in terms of releases from Building 12 stacks is the Group 18 Housing west of the airport. Figures 15-6 and 15-7 show the locations of DP Site and relevant housing areas. The closest of these homes were 0.25 mi from DP West, and winds blew in their direction (NNW) an average of 6.0% of the time. Other Los Alamos housing areas of interest include Early Postwar Housing, such as the Denver Steel, Ft. Leonard Wood, Hanford, and Wingfoot housing developments. These areas were located 0.5 to 2.5 mi northwest of DP West, and winds blew in this direction 3.7% of the time. The trailer park south of DP Road should also be considered, since it was located 0.5 mi directly west from DP West, and winds blew in this direction 3.5% of the time. Finally, the Replacement Housing (see symbol C in Figure 15-6), is an area of interest, since it was constructed as close as 0.5 mi west-northwest of DP West, and wind blew in this direction 3.4% of the time.

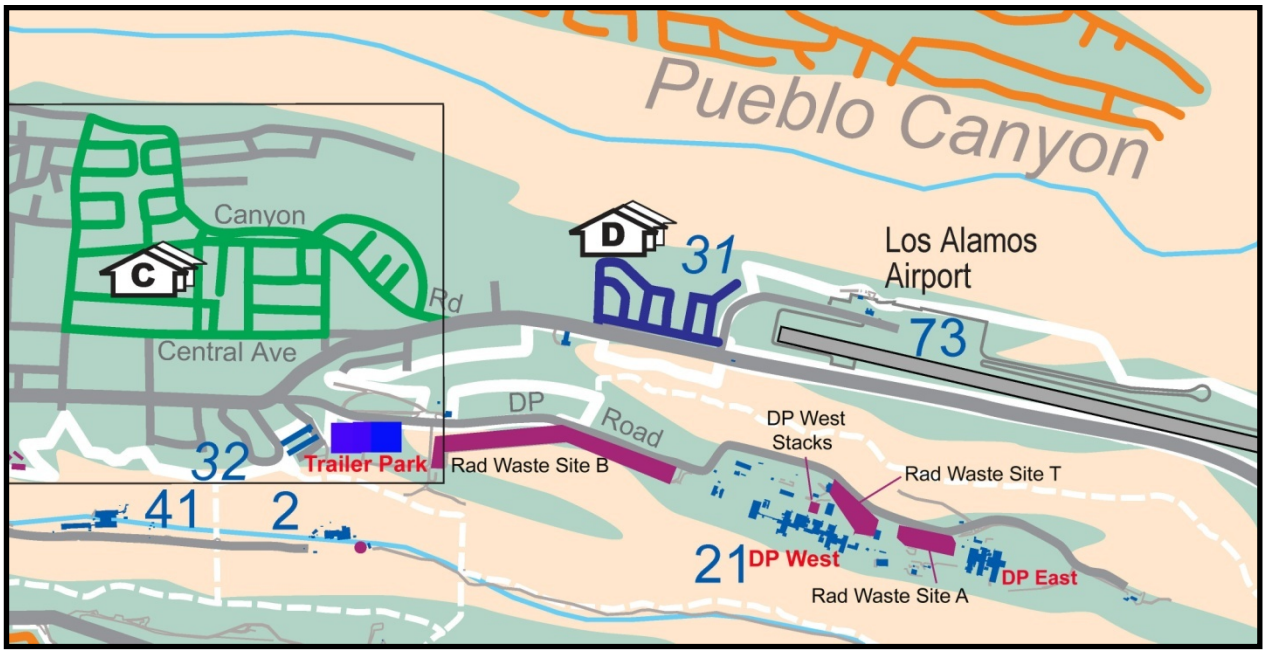


Fig. 15-6: Location of DP Site relative to LANL housing areas. Group 18 housing west of the airport (housing symbol D) was established 1957-1958. Replacement housing (symbol C, established 1953-57) took the place of wartime and early postwar housing (See Figure 6-1), of which the closest to DP Site would have been the trailer park south of DP Road. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

c. DP East (TA-21; with Releases from Buildings 152 and 153)

DP East started up in 1945 and processed polonium and actinium and to produce initiators. Building 153 served as the exhaust building for DP East until it shut down in 1970. A public area for consideration in terms of DP East operations is Group 18 Housing by the airport (see Figures 15-6 and 15-7). These homes were 0.5 to 0.75 mi northwest of DP East, and the wind blew in their direction approximately 3.7% of the time. Before the housing by the airport was established, Wartime and Early Postwar Housing, and Replacement Housing would be areas for consideration. The trailer park south of DP Road was approximately 0.9 mi WNW of DP East, and the wind blew in that direction 3.4% of the time.

d. Omega Site Reactors

Omega Site was established in 1943 and has housed three different reactors: the Water Boilers (three versions), the Plutonium Fast Reactor, and the Omega West Reactor. Because of the perceived danger of the work to be performed, Omega Site was built at the bottom of Los Alamos Canyon away from the original Technical Area (LANL, 1997, Hunner, 2004). Initially, a flexible off-gas line carried reactor effluents from the bottom of the canyon to the top of South Mesa for discharge (LASL, 1947). In later years, a more conventional stack was built on top of South Mesa. Royal Crest Trailer Park, which sits on South Mesa 0.25 mi south of Omega Site, and the trailer park just south of DP Road, which around 1948

through 1963 was situated on Los Alamos Mesa directly above Omega Site, are potential public areas of consideration for the Omega Site releases (see Figures 15-8 and 15-9).

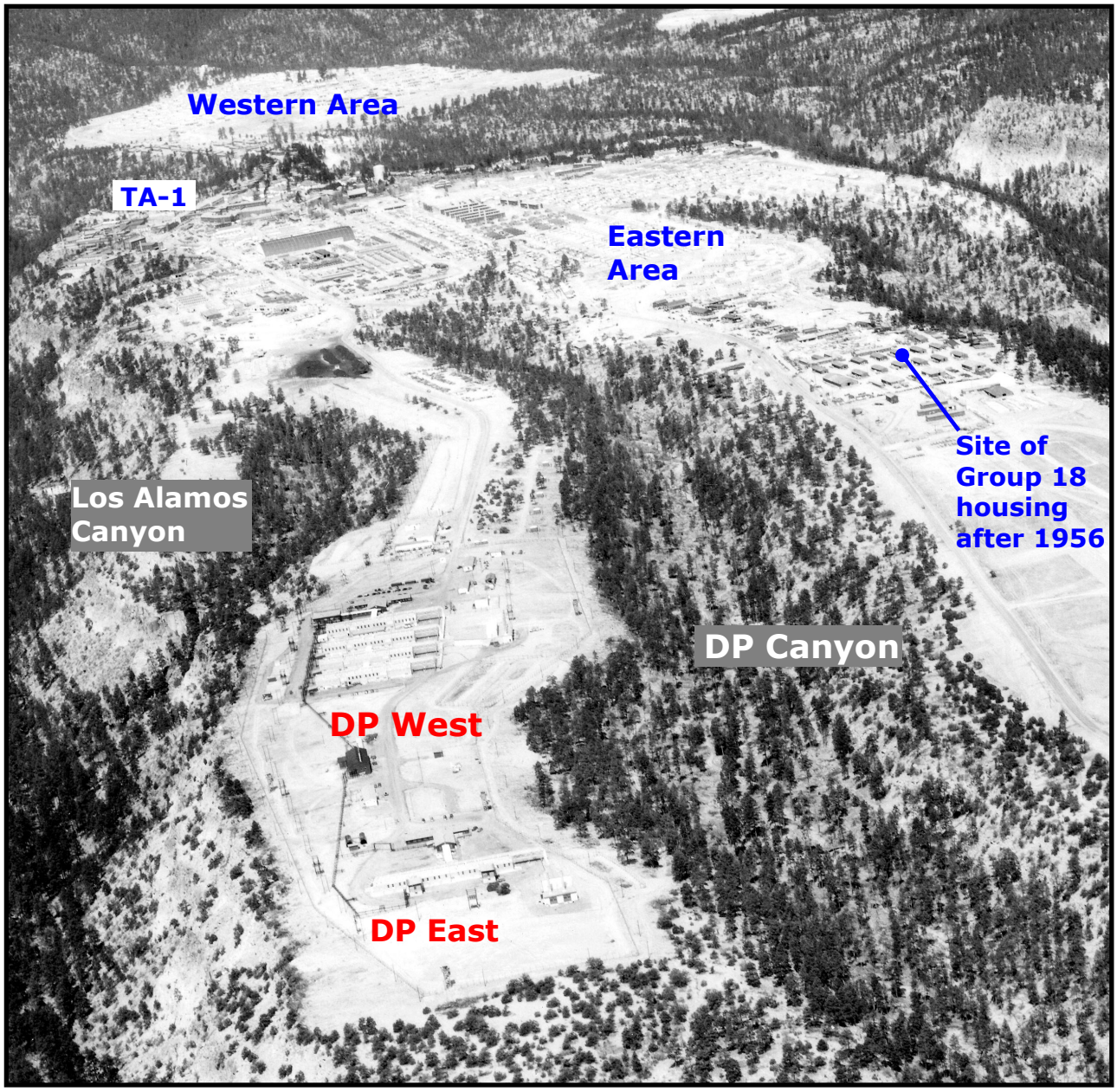


Fig. 15-7: Aerial view of Los Alamos (circa 1947, looking west) shows DP East (lower center), DP West above it, and Los Alamos townsite in the background. Residential areas shown include Western Area at the upper left, Eastern Area in the upper center, and the area west of (above) the airport that became the site of Group 18 housing at the upper right. *Photo courtesy Los Alamos Historical Society* (*LAHM-P1990-40-1-3114).*

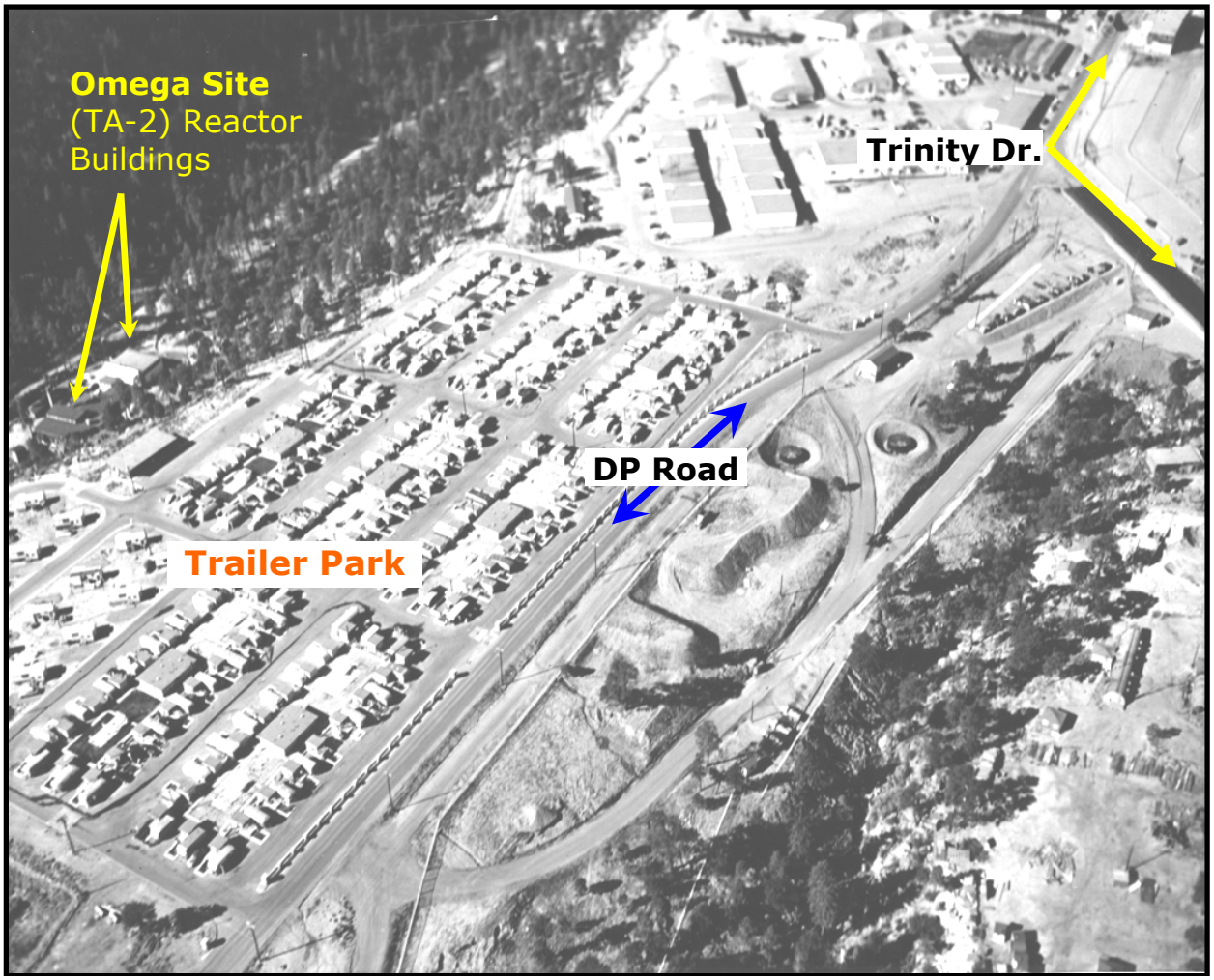


Figure 15-8: This 1949 photo shows a mobile home park located south of DP Road close to Trinity Drive. Located directly above the Omega Site reactor buildings in Los Alamos Canyon (upper left corner), the park included both private mobile homes and Wingfoot trailers supplied by the government. This area eventually became known as Royal Crest park. By August 30, 1963, all occupants were required to move out; some relocated to the "new" Royal Crest trailer park on East Jemez Road (*Los Alamos Monitor*, August 23, 1963). West of (above) the park are Zia Company warehouses and service buildings that supported TA-1. *Photo courtesy Los Alamos Historical Society* (LAHM-P1989-13-1-1917*).*

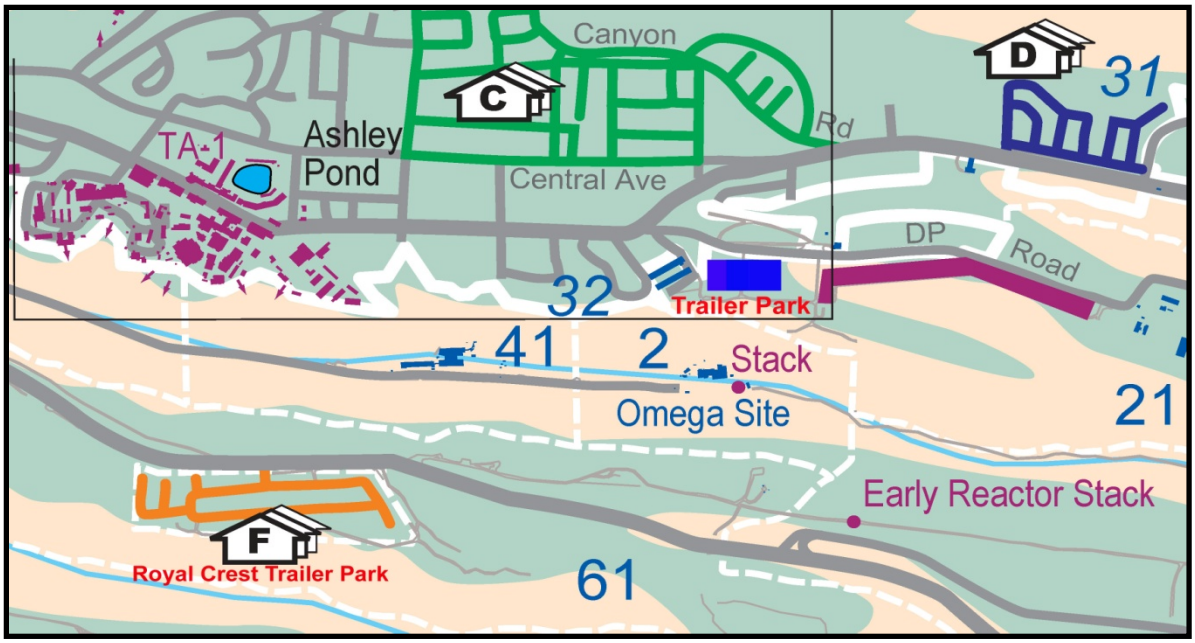


Figure 15-9: Location of Omega Site and associated reactor stacks relative to several Los Alamos housing areas. The trailer park south of DP Road was established around 1948, remained in use through at least 1963, and was gone by 1979. Royal Crest Trailer Park was established in 1960, and remains in use. Reactors operated at Omega Site until 1992. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

e. TA-3, the current main Technical Area.

In 1953, LANL main technical facilities moved from TA-1, across Los Alamos Canyon, to TA-3. Various buildings at TA-3 have housed plutonium, uranium, machining, and accelerator operations over the years. An area of interest for releases from TA-3 is the Western Area, located 0.5 to 1 mi north of the center of TA-3 (see Figures 15-10 and 15-11). LANL winds blew toward the north 8.8% of the time. Other possible housing areas to consider in terms of TA-3 are Replacement Housing, which were constructed beginning in 1953, and Royal Crest Trailer Park, which opened in 1960. The closest Replacement Housing to TA-3, which is approximately 0.5 mi northeast of TA-3, lies south of Trinity Drive and east of Diamond Drive. Winds blew in the northeast direction 7.7% of the time, as averaged over a ten year period. Winds blew toward Royal Crest Trailer Park about 11.4% of the time.

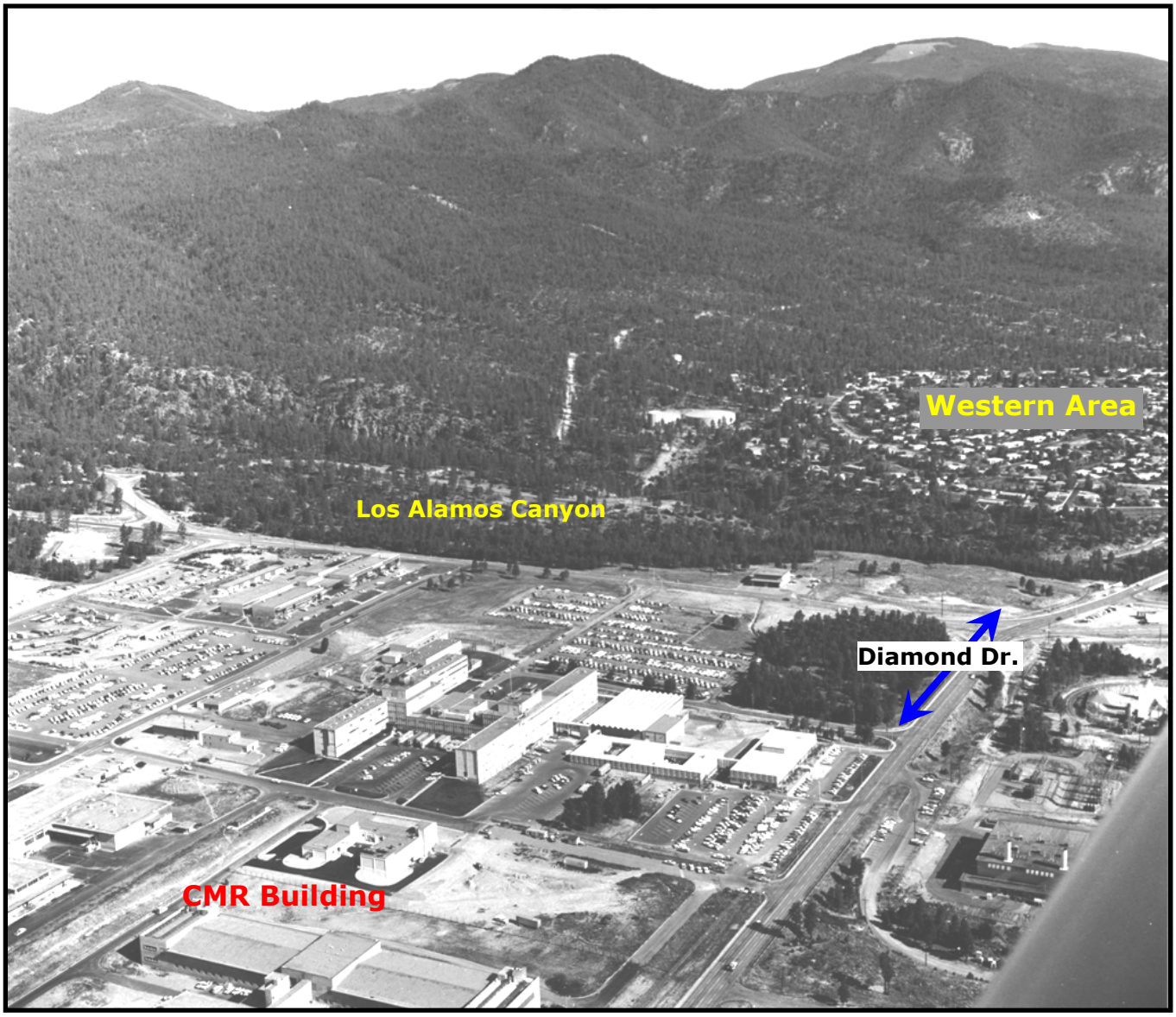


Figure 15-10: This aerial photo (circa 1967) looks across TA-3 and Los Alamos Canyon to the Western Area and the Jemez Mountains. The "H"-shaped LANL Administration Building and surrounding structures are in the foreground, Diamond Drive runs through the lower right quadrant of the frame, and part of the CMR Building is visible at the lower left edge. *Photo courtesy Los Alamos Historical Society (LAHM-P2000-2-1-7144).*

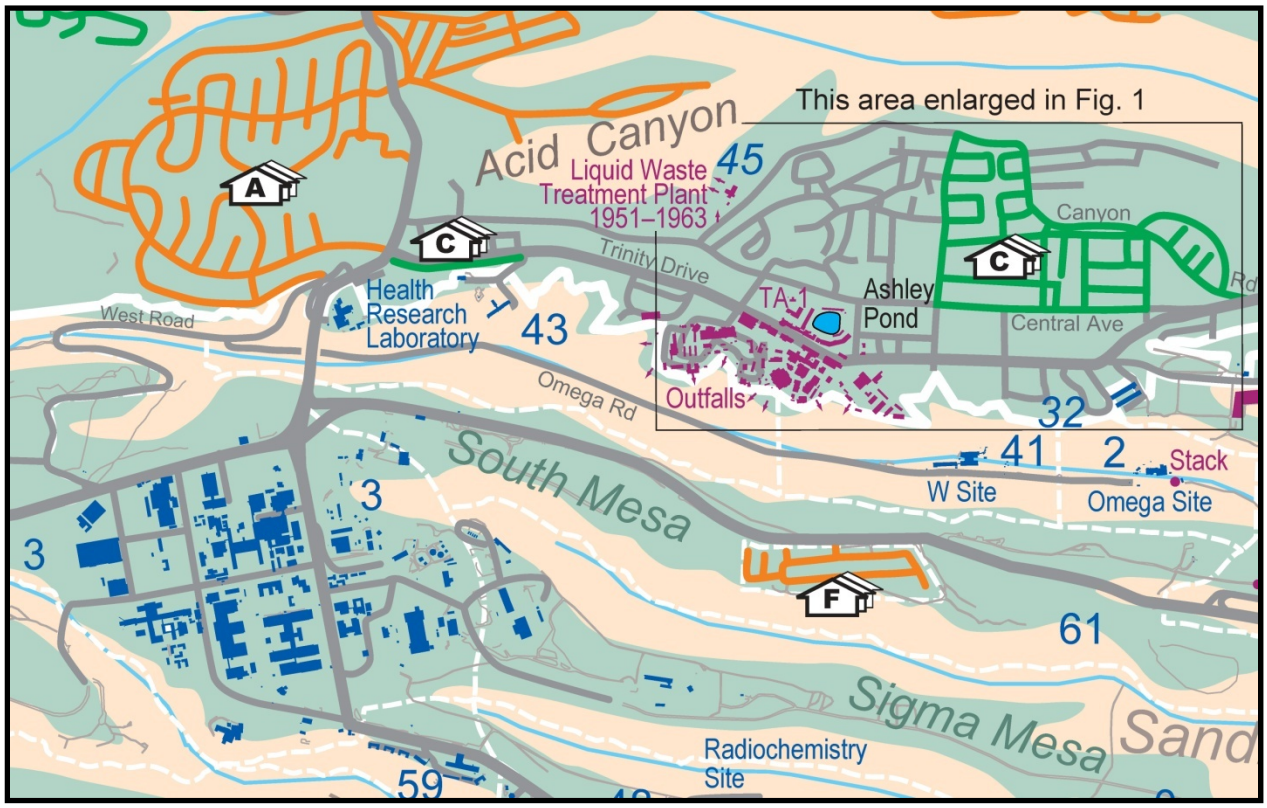


Fig. 15-11: Location of TA-3 (lower left, established 1953) to some Los Alamos housing areas. Western Area (housing symbol A) was established in 1946; "replacement housing" (symbol C) was constructed 1953-1957, and Royal Crest Trailer Park opened in 1960. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

f. LAMPF (now LANSCE)

LAMPF (Los Alamos Meson Physics Facility), which is now called LANSCE (Los Alamos Neutron Science Center), is a large accelerator complex located on Mesita de Los Alamos (Figure 15-12). Construction began in 1968, and the facility still operates today. The location of the off-site maximally exposed (hypothetical) individual in LANL's annual environmental radiological dose assessments has typically been at the East Gate/Philomena's area on State Road 502, where it enters the east side of Los Alamos County (LANL, 2001). This location was selected because of its proximity to LANSCE, which is reflected in Figure 15-13. Philomena's restaurant was once located 0.5-mi north-northeast of the center of the LANSCE complex. According to the ten year average wind rose, the LANL winds blew in this direction 8.3% of the time.

Figure 15-12: Aerial view of LANSCE looking towards the southwest. *Photo courtesy of LANL.*

Figure 15-13: Location of LANSCE relative to several public areas near LANL.*Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

g. High explosives manufacturing areas

Since the 1940s, high explosive research, development, and testing at LANL has been conducted in over 25 different Technical Areas. The S-Site was chosen as the high explosive manufacturing area example for the purposes of this report because it was the main site of early explosives processing facilities. S-Site (Figure 15-14) was developed in 1943 for the high explosive production, and remains in operation today. A public area of interest for the S-Site is the Western Area, which is located 2.75 mi north northeast of this site (see Figure 15-15). The winds blow from the S-Site and in the direction of the Western Area 8.3% of the time. Other areas to consider with regards to the S-Site are Wartime Housing, Replacement Housing, and Early Postwar Housing, all of which were located approximately three mi from S-Site and experienced winds in their direction about 8% of the time.

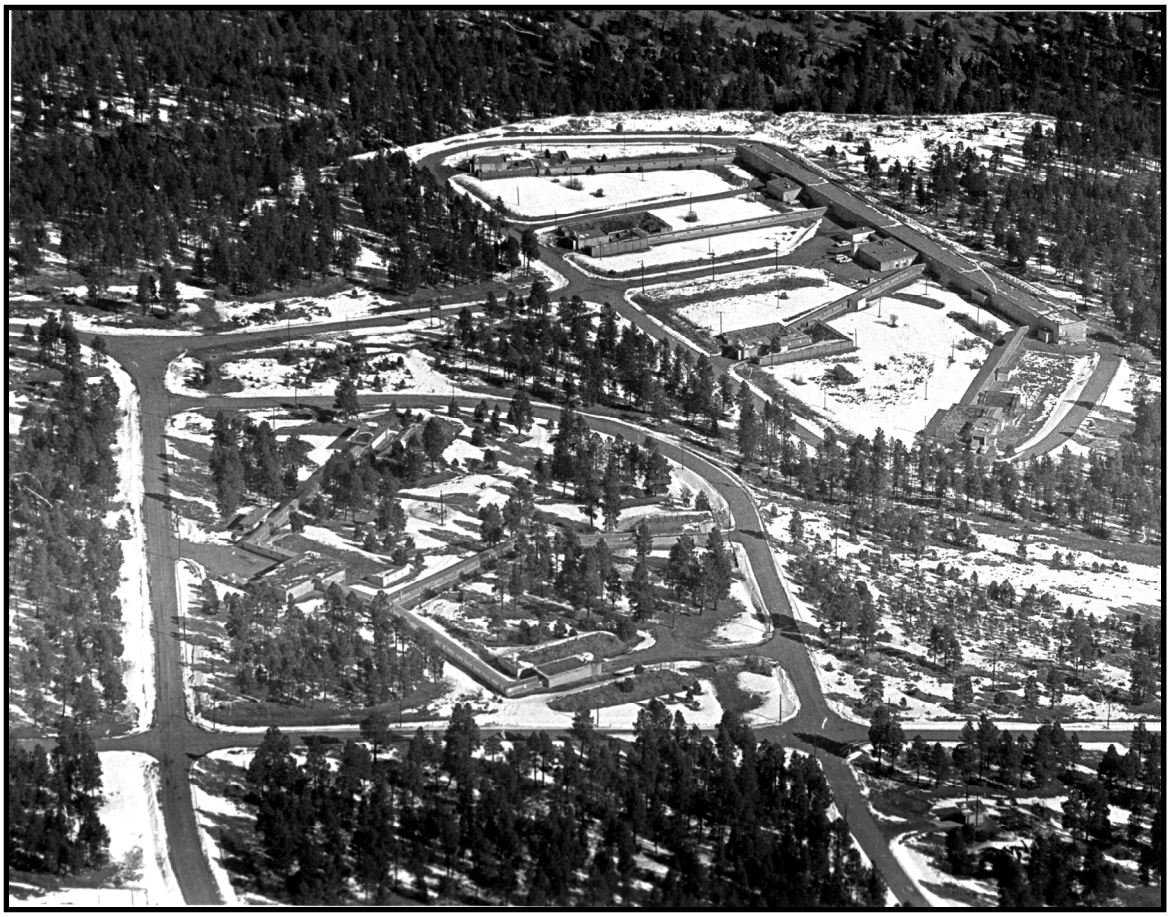


Figure 15-14: High explosives manufacturing facilities were constructed in areas more distant from residential areas than original Technical Area buildings, and wider separation between buildings reflected the more readily recognized safety hazards of associated operations. This August, 1952 aerial view of TA-16 shows Building 260 in the upper right of the image. These buildings for machining high explosives were made of concrete, and had special walls in the back that were built to blow out in the event of an accident. The image shows forested land above and below TA-16. *Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-3138).*

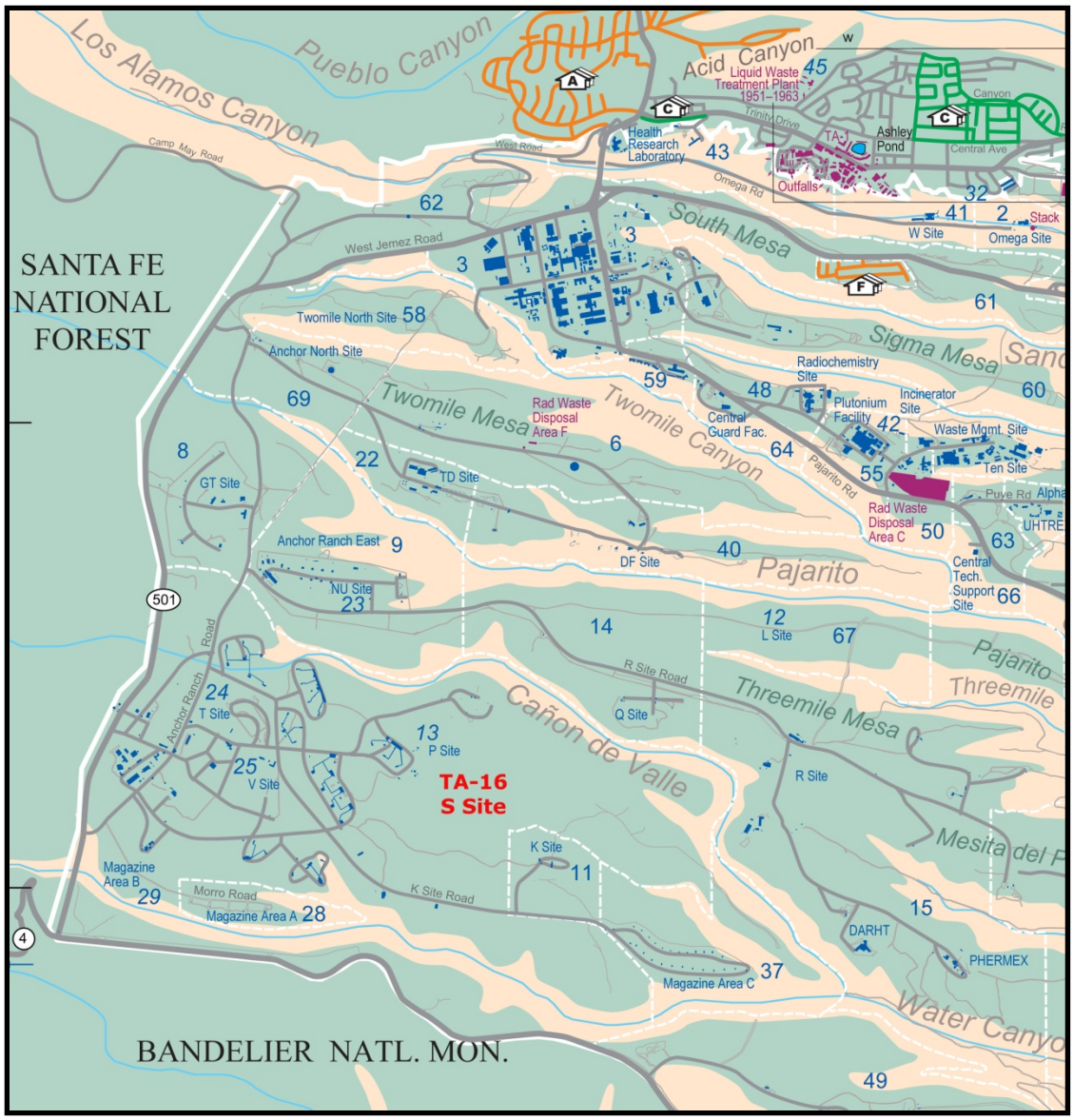


Fig. 15-15. Location of TA-16 (S-Site) relative to public areas of Los Alamos. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

h. High Explosives Firing Sites

There have been a number of high explosive firing sites at LANL. R-Site was chosen as the example for this report. Eight firing sites (A-H) were established at R-Site between 1944 and 1948, and operations at R-Site continue today. Royal Crest Trailer Park, which is located 2 mi north-northeast of the site, is the closest public area to R-Site and is an area of interest (see Figure 15-16). According to the LANL wind data, winds blow from R-Site towards the trailer park 8.3% of the time. Since R-Site began operations in 1944, earlier housing should also be considered when evaluating R-Site releases. Wartime Housing, Early Postwar Housing, and Replacement Housing were all about 2.5 mi to the north, north-northeast, and north-northeast, respectively. Winds blow in these directions 8% to 9% of the time.

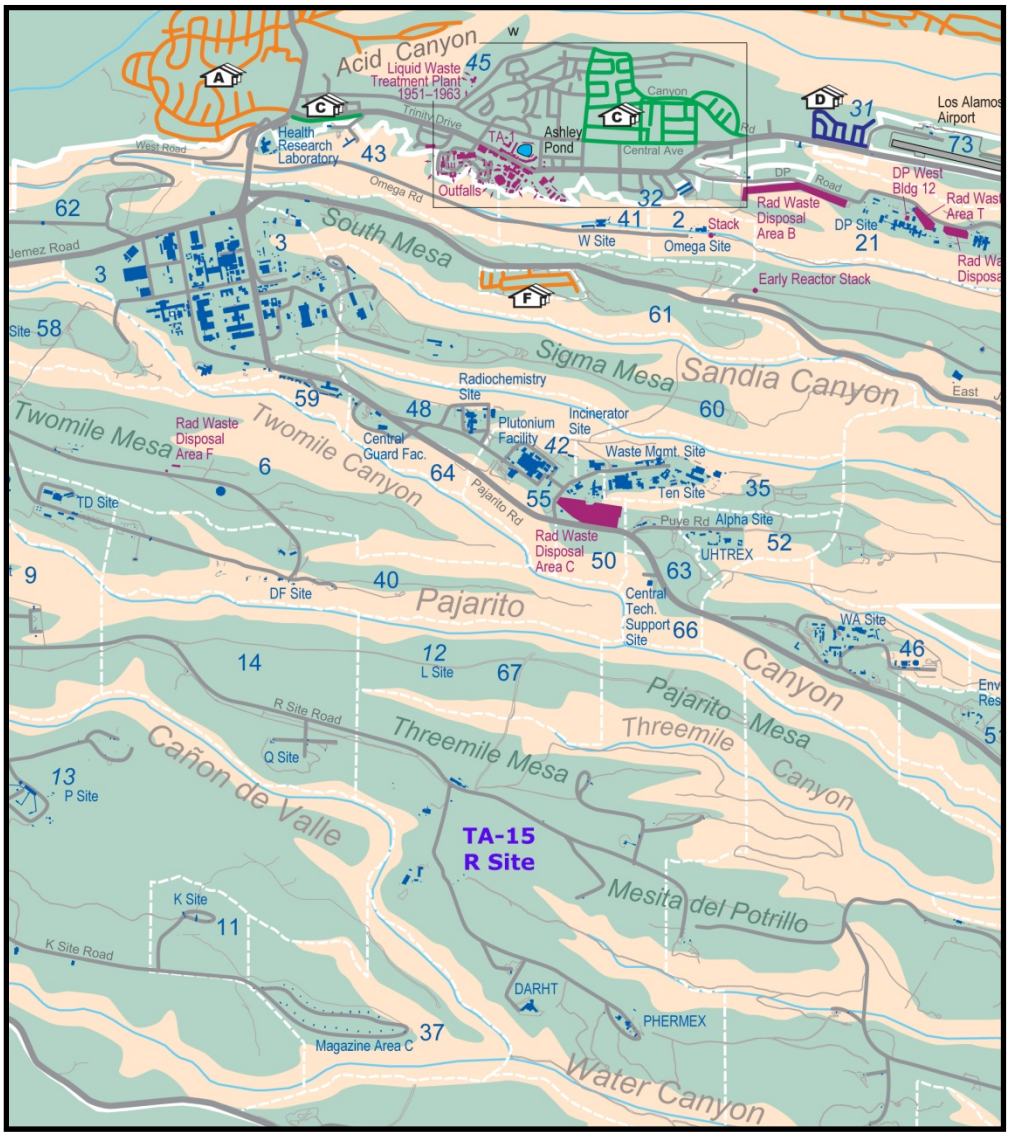


Figure 15-16: Location of TA-15 (R Site) relative to public areas of Los Alamos. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

i. Bayo Canyon Firing Site

The Bayo Canyon Site (TA-10) was used between 1944 and 1962 for experiments using conventional high explosives, radioactive lanthanum (RaLa), and, in some cases, depleted or natural uranium. Its location is shown in Figure 15-17. A public area of interest for the Bayo Canyon site is the Totavi Camp, located five mi east-southeast of the site down the Bayo Canyon. Since operations at this site were conducted in a canyon that runs approximately east to west, wind tends to blow back and forth down this canyon. The Totavi Camp was located east south east of the Bayo Canyon site, and wind traveled in this direction 11.9% of the time. Also of interest because of these canyon winds is the North Community, which is located 2.5 mi directly west of the Bayo Canyon site. Winds blew in the direction of the North Community 3.5% of the time.

Figure 15-17: Location of Point Able site that was the location of many RaLa shots between 1944 and 1962. The North Community (established in 1948) is at the left of the figure (labeled with housing symbol B), and San Ildefonso Pueblo lands are east of the LANL boundary at the lower right. Areas associated with housing symbols A, E, G, and H indicate residential areas that were established in 1946, 1958, 1977, and the late 1970s, respectively. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*

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Chapter 16: Partial Chronology of Accidents, Incidents, and Events at LANL

An important part of the historical record review of LANL operations focused on Health Division and other records that included descriptions of accidents or incidents that were potentially associated with off-site releases or health effects. Some of the incidents of interest include chemical releases, fires, explosions, radiation exposures to workers, and other notable accidents that occurred at LANL. The incidents that are potentially relevant to off-site releases or health effects are of particular importance.

The LAHDRA team, based on its review of reports and correspondence, compiled a partial chronology of accidents, incidents, and events that occurred at LANL. The information presented in Table 16-1 is a partial chronology, however, because the information was collected from many sources, and so it is unlikely that all reports documenting accidents and incidents were found. Minor worker contamination incidents were not included, nor were easily cleaned up spills of small amounts of low toxicity materials onto solid surfaces. The quantity and type of contamination released is reported when available.

Health Division reports in the database were first reviewed for incidents of interest. Next, the LAHDRA DocSleuth database was searched for selected document types (such as health reports and quarterly or monthly H Division progress reports) to obtain additional documents to review. The additional documents identified via that search were reviewed, and incidents of interest were recorded. Next, the search was expanded to include documents relevant to criticality incidents, explosions, and RaLa shots.

In Table 16-1, the first column lists either the stated date of the incident or event or an estimated date based on the date of the source document.

The second column contains a brief description of the incident or event. Any qualitative descriptions or impressions given are those of the original document's authors, as are any release quantities or off-site measurements. The original document text is available for viewing in case questions arise or additional information or context is desired.

The third column in the table contains a categorization of each event. Each event was categorized based on the incident type and the potential for off-site release or possible adverse health effects. The categories used were:

- Accident – An incident not involving radioactive or dangerous material
- Air Release – An incident involving the release of air contamination
- Criticality – An event in which a mass of radioactive material went "critical"
- Equipment Malfunction – An incident resulting from equipment failure
- Explosion – An incident involving an explosion
- Fire – An incident involving fire
- Liquid Release – An incident involving the release of liquid contamination
- RaLa Shot – An explosive test event involving radioactive lanthanum
- User Error – An event involving a human error
- Contamination Event – Any additional unclassifiable contamination event

The fourth column contains the LAHDRA Repository Number of the source document. In some cases, documents contained so many pages that their image files were divided into pieces to facilitate downloading. In these cases, the Repository Number may be followed by a letter: "338f," for example, would indicate the sixth part of a large document having at least six PDF image files.

The fifth and final column in Table 16-1 contains the page number at which the description of the described incident or event begins. This page number refers to the PDF file, which, in many cases, may differ from the page number shown on the original document page, since cover pages and early pages of a printed document are often not numbered, or, in some cases, not all pages from the source document were requested by the LAHDRA document analysts or released by LANL.

Over 30,000 pages in over 500 documents were reviewed in order to prepare the chronology of accidents and incidents. These documents included:

- Contamination incident reports
- Incident report investigation files
- Miscellaneous laboratory incident memorandums
- Radiation occurrence reports
- A review of criticality accidents

- A survey of liquid waste management problems at LANL
- Monthly and annual reports of DP West Site operations
- Annual reports of the Health Division
- Health physics/radiation protection quarterly reports
- Incidents and accidents involving explosives at LANL
- Reports of the Bayo Canyon/Radioactive Lanthanum (RaLa) Program
- Airborne Contamination Annual Summaries
- Summaries of LANL Health Hazards

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
9/21/1944	RaLa shot # 1 took place on 9/21/1944 at ~1610 hours. The shot involved ~25 to 60 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/4/1944	RaLa shot # 2 took place on 10/4/1944 at 1937 hours. The shot involved 120 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/14/1944	RaLa shot # 3 took place on 10/14/1944 at 1651 hours. The shot involved 60 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/26/1944	RaLa shot # 4 took place on 10/26/1944 at 1540 hours. The shot involved 185 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
11/3/1944	RaLa shot # 5 took place on 11/3/1944 at ~1645 hours. The shot involved 113 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa at dwelling T-846, near the present corner of Rim and Canyon Roads, which was the nearest habitation to the firing point. The purpose was apparently to detect any radioactivity that might be carried to the Los Alamos town site, although whether or not Los Alamos was downwind was not recorded. The air samplers were run during each shot and for some time after the shot was fired. The results of each sample were negative, indicating that no radioactivity from these shots reached the town site.	RaLa Shot	2	all
12/1/1944	RaLa shot # 6 took place on 12/1/1944 at 1630 hours. The shot involved 280 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/10/1944	RaLa shot # 7 took place on 12/10/1944 at 635 hours. The shot involved 90 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/14/1944	RaLa shot # 8 took place on 12/14/1944 at 2158 hours. The shot involved 110 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/20/1944	RaLa shot # 9 took place on 12/20/1944 at 1445 hours. The shot involved 82 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/28/1944	RaLa shot # 10 took place on 12/28/1944 at 1535 hours. The shot involved 47 Ci of RaLa with an explosive charge of 20 to 100 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/7/1945	RaLa shot # 11 took place on 2/7/1945 at 1310 hours. The shot involved 220 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/11/1945	On February 11, 1945 there was a criticality incident involving UH_3 pressed in styrex. The assembly went prompt critical during the dropping of a slug of the active material through a vertical hole. The UH3-styrex cubes were swollen and blistered from the heat of the reaction. ~6×10^{15} total fissions were involved.	Criticality	6206	all
2/13/1945	RaLa shot # 12 took place on 2/13/1945 at 1945 hours. The shot involved 240 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/18/1945	RaLa shot # 13 took place on 2/18/1945 at 1626 hours. The shot involved 240 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/24/1945	RaLa shot # 14 took place on 2/24/1945 at 1644 hours. The shot involved 135 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
3/3/1945	RaLa shot # 15 took place on 3/3/1945 at 2226 hours. The shot involved 70 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
4/1/1945	RaLa shot # 16 took place on 4/1/1945 at 1645 hours. The shot involved 290 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative. The date for one of the air samples was recorded as March 31, 1945; however, no shot was fired on that date. Since shot #16 was fired on April 1,1945, the March 31,1945, date is believed to be in error.	RaLa Shot	2	all
4/9/1945	RaLa shot # 17 took place on 4/9/1945 at 120 hours. The shot involved 530 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the ESE. An air sampler was run on Los Alamos Mesa (location unknown) during the shot and for 8 hours afterward. No activity was found.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
4/15/1945	RaLa shot # 18 took place on 4/15/1945 at 2035 hours. The shot involved 215 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the ESE. An air sampler was run at Technical Area 1 (TA-1, the main technical area) for 24 hours to check for contamination. A reading of 50 counts per minute (cpm) gamma radiation was found. "This was the first time that any airborne contamination [associated with Bayo Canyon] was picked up on the mesa."	RaLa Shot	2	all
4/20/1945	RaLa shot # 19 took place on 4/20/1945 at 1841 hours. The shot involved 220 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/26/1945	RaLa shot # 20 took place on 4/26/1945 at 2143 hours. The shot involved 150 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
5/11/1945	On May 11, 1945 an accident occurred in Room B2 of Gamma Building. A rotating shield struck a piece of Po metal, sending contamination through out the lab.	Contam. Event	3496	8
5/22/1945	RaLa shot # 21 took place on 5/22/1945 at 1547 hours. The shot involved 620 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/26/1945	RaLa shot # 22 took place on 5/26/1945 at 1700 hours. The shot involved 450 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/30/1945	RaLa shot # 23 took place on 5/30/1945 at 1500 hours. The shot involved 342 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
6/4/1945	RaLa shot # 24 took place on 6/4/1945 at 1630 hours. The shot involved 900 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
6/6/1945	On June 6, 1945 there was a criticality incident involving 35.4 kg U-235 in 1/2-inch cubes. The pseudo sphere went critical during water seeping between the blocks. ~3x 10^{16} total fissions were involved.	Criticality	6206	all
6/8/1945	RaLa shot # 25 took place on 6/8/1945 at 1545 hours. The shot involved 795 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/13/1945	RaLa shot # 26 took place on 6/13/1945 at 1535 hours. The shot involved 569 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
6/16/1945	RaLa shot # 27 took place on 6/16/1945 at 1508 hours. The shot involved 367 Ci of RaLa with an explosive charge of 201 to 350 lbs. A high-capacity air sampler was run at the edge of Los Alamos Mesa in front of civilian dwelling T-843 (probably T-846). Thirteen thousand five hundred (13,500) liters of air were sampled, and the beta plus gamma activity on the filter was less than 10 cpm (background). Another sampler was set up at TA-1 in front of Q Building. Results were also negative	RaLa Shot	2	all
6/22/1945	RaLa shot # 28 took place on 6/22/1945 at 1530 hours. The shot involved 1060 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/26/1945	RaLa shot # 29 took place on 6/26/1945 at 1724 hours. The shot involved 737 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/29/1945	RaLa shot # 30 took place on 6/29/1945 at 1700 hours. The shot involved 393 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/6/1945	RaLa shot # 31 took place on 7/6/1945 at 1718 hours. The shot involved 343 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/14/1945	RaLa shot # 32 took place on 7/14/1945 at 1715 hours. The shot involved 190 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
7/16/1945	**The world's first nuclear explosion took place at the Trinity site in southern New Mexico at 5:29 a.m.**		various	
8/3/1945	RaLa shot # 33 took place on 8/3/1945 at 2145 hours. The shot involved 471 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/6/1945	**Little Boy gun type atomic bomb dropped on Hiroshima, Japan.**			
8/9/1945	**Fat Man implosion type atomic bomb dropped on Nagasaki, Japan.**			
8/10/1945	RaLa shot # 34 took place on 8/10/1945 at 1531 hours. The shot involved 240 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
8/15/1945	RaLa shot # 35 took place on 8/15/1945 at 1530 hours. The shot involved 168 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
8/21/1945	On August 21, 1945 there was a criticality incident involving 6.2 kg gamma-phase Pu. An experimenter was hand stacking tungsten carbide blocks around a Pu mass. The experimenter accidentally dropped a block allowing the Pu to go critical. 1 death and 1 injury resulted from the accident. ~10^{16} total fissions were involved.	Criticality	6206	all
8/24/1945	RaLa shot # 36 took place on 8/24/1945 at 1556 hours. The shot involved 1200 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/1/1945	RaLa shot # 37 took place on 9/1/1945 at 1620 hours. The shot involved 1050 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/8/1945	RaLa shot # 38 took place on 9/8/1945 at 1740 hours. The shot involved 628 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all

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9/13/1945	RaLa shot # 39 took place on 9/13/1945 at 1615 hours. The shot involved 440 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
9/20/1945	RaLa shot # 40 took place on 9/20/1945 at 1415 hours. The shot involved 380 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
9/25/1945	RaLa shot # 41 took place on 9/25/1945 at 1740 hours. The shot involved 1291 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/26/1945	There was a fire in the contaminated pit September 26, 1945. Contamination was found on the fence surrounding the area and on the guard tower next to the dump.	Fire	4525	3-5
10/1/1945	RaLa shot # 42 took place on 10/1/1945 at 1716 hours. The shot involved 772 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/6/1945	RaLa shot # 43 took place on 10/6/1945 at 1605 hours. The shot involved 446 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/12/1945	RaLa shot # 44 took place on 10/12/1945 at 1620 hours. The shot involved 516 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
11/28/1945	On November 28, 1945 in Room 76 of DP Site a worker noticed that a container of Po had leaked. The room was decontaminated.	Liquid Release	4525	2
12/14/1945	RaLa shot # 45 took place on 12/14/1945 at 1655 hours. The shot involved 345 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
12/28/1945	RaLa shot # 46 took place on 12/28/1945 at 1620 hours. The shot involved 1340 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/4/1946	RaLa shot # 47 took place on 1/4/1946 at 1628 hours. The shot involved 954 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/11/1946	RaLa shot # 48 took place on 1/11/1946 at 1600 hours. The shot involved 647 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/17/1946	RaLa shot # 49 took place on 1/17/1946 at 1530 hours. The shot involved 459 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
1/24/1946	RaLa shot # 50 took place on 1/24/1946 at 1610 hours. The shot involved 1712 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W. The maximum radiation measured at distance (mR/h) was 0.046 mR/h at 2 miles. The cloud from the shot drifted toward TA-1. Gamma radiation measurements throughout the technical area ranged from 0.028 to 0.046 mR/h. Normal background is about 0.028 mR/h	RaLa Shot	2	all
1/31/1946	RaLa shot # 51 took place on 1/31/1946 at 1555 hours. The shot involved 1057 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
2/7/1946	RaLa shot # 52 took place on 2/7/1946 at 1537 hours. The shot involved 654 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/14/1946	RaLa shot # 53 took place on 2/14/1946 at 1602 hours. The shot involved 454 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
3/21/1946	RaLa shot # 54 took place on 3/21/1946 at 1520 hours. The shot involved 1034 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/28/1946	RaLa shot # 55 took place on 3/28/1946 at 1447 hours. The shot involved 848 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/12/1946	RaLa shot # 56 took place on 4/12/1946 at 1555 hours. The shot involved 315 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
4/15/1946	There was a tuballoy fire in the Tech area on April 15, 1946. Firemen were exposed directly to tuballoy smoke without protective equipment.	Fire	4285	11
4/25/1946	RaLa shot # 57 took place on 4/25/1946 at 1520 hours. The shot involved 1324 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/2/1946	RaLa shot # 58 took place on 5/2/1946 at 1500 hours. The shot involved 890 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/3/1946	There was a explosion in a drybox in Room 107 of D Building on May 3, 1946. The room and adjoining hallway were contaminated.	Explosion	4526	2
5/9/1946	RaLa shot # 59 took place on 5/9/1946 at 1440 hours. The shot involved 600 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
5/16/1946	RaLa shot # 60 took place on 5/16/1946 at 1535 hours. The shot involved 279 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
5/21/1946	On May 21, 1946 there was a criticality incident involving 6.2 kg of delta-phase Pu. An experimenter was holding two hemispheres of Pu apart with a screw driver as a demonstration to a group. When the screw driver slipped, it allowed the spheres to come together to form a critical mass. 1 death and 7 injuries resulted from the accident. ~$3X10^{15}$ total fissions were involved.	Criticality	6206	all
5/23/1946	RaLa shot # 61 took place on 5/23/1946 at 1440 hours. The shot involved 1274 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/29/1946	RaLa shot # 62 took place on 5/29/1946 at 1450 hours. The shot involved 931 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/6/1946	RaLa shot # 63 took place on 6/6/1946 at 1445 hours. The shot involved 539 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/27/1946	RaLa shot # 64 took place on 6/27/1946 at 1440 hours. The shot involved 1494 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all

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7/3/1946	RaLa shot # 65 took place on 7/3/1946 at 1625 hours. The shot involved 976 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/11/1946	Pu metal turnings caught fire in a drybox in Room 317 on July 11, 1946. The room was highly contaminated.	Fire	4526	4
7/11/1946	RaLa shot # 66 took place on 7/11/1946 at 1423 hours. The shot involved 702 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
7/18/1946	RaLa shot # 67 took place on 7/18/1946 at 1530 hours. The shot involved 516 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
8/1/1946	The first fatality involving energetic materials at Los Alamos was at the Omega-West Reactor Site in August 1946. Thre employees mixed potassium chlorate, sugar, magnesium turnings, and red phosphorous. One person died when the mixture ignited, and two others were injured.	Explosion	6203	9
8/28/1946	RaLa shot # 68 took place on 8/28/1946 at 2245 hours. The shot involved 1026 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
11/15/1946	There was a fire in the contaminated dump on November 15, 1946.	Fire	4526	1
12/19/1946	RaLa shot # 69 took place on 12/19/1946 at 1640 hours. The shot involved 1261 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/27/1946	RaLa shot # 70 took place on 12/27/1946 at 2202 hours. The shot involved 610 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/3/1947	RaLa shot # 71 took place on 1/3/1947 at 1920 hours. The shot involved 467 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/16/1947	On January 16, 1947 a worker cutting $Pu(NO_3)_4$ spilled approximately 70 mg of solution on their pants and the floor of D-146.	User Error	3482	2
1/23/1947	On January 23, 1947 a worker with a sledge hammer hit a 5 gallon bottle containing plutonium residue releasing approximately 30 mg of Pu in the basement of D Building. The ground was dug up and buried in the waste disposal pit.	User Error	3482	4
3/10/1947	RaLa shot # 72 took place on 3/10/1947 at 2200 hours. The shot involved 570 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/14/1947	RaLa shot # 73 took place on 3/14/1947 at 1758 hours. The shot involved 720 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/19/1947	RaLa shot # 74 took place on 3/19/1947 at 1952 hours. The shot involved 630 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/11/1947	RaLa shot # 75 took place on 4/11/1947 at 140 hours. The shot involved 480 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/16/1947	RaLa shot # 76 took place on 4/16/1947 at 1832 hours. The shot involved 640 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/6/1947	RaLa shot # 77 took place on 5/6/1947 at 1540 hours. The shot involved 1341 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/13/1947	RaLa shot # 78 took place on 5/13/1947 at 1655 hours. The shot involved 1141 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/21/1947	RaLa shot # 79 took place on 5/21/1947 at 1926 hours. The shot involved 574 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/18/1947	RaLa shot # 80 took place on 6/18/1947 at 1438 hours. The shot involved 170 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/25/1947	RaLa shot # 81 took place on 6/25/1947 at 1319 hours. The shot involved 1290 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/2/1947	RaLa shot # 82 took place on 7/2/1947 at 1800 hours. The shot involved 1320 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/10/1947	RaLa shot # 83 took place on 7/10/1947 at 1703 hours. The shot involved 851 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
7/30/1947	RaLa shot # 84 took place on 7/30/1947 at 1850 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/6/1947	RaLa shot # 85 took place on 8/6/1947 at 1706 hours. The shot involved 700 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/13/1947	RaLa shot # 86 took place on 8/13/1947 at 1545 hours. The shot involved 680 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
8/27/1947	RaLa shot # 87 took place on 8/27/1947 at 2022 hours. The shot involved 1610 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/4/1947	RaLa shot # 88 took place on 9/4/1947 at 1655 hours. The shot involved 925 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/11/1947	RaLa shot # 89 took place on 9/11/1947 at 1625 hours. The shot involved 670 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/18/1947	RaLa shot # 90 took place on 9/18/1947 at 1420 hours. The shot involved 438 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
10/22/1947	A fire was detected on October 22, 1947 in the contaminated dump. The results of monitoring during and after the fire reportedly indicated that there was no significant exposure to radioactive materials.	Fire	4285	8
10/29/1947	RaLa shot # 91 took place on 10/29/1947 at 1543 hours. The shot involved 1670 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all

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11/5/1947	RaLa shot # 92 took place on 11/5/1947 at 1522 hours. The shot involved 946 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
11/7/1947	On November 7, 1947 pressurized radioactive spray was released from a line of the peroxider unit contaminating one worker.	Equipment Malfunction	3482	11
11/12/1947	RaLa shot # 93 took place on 11/12/1947 at 1543 hours. The shot involved 730 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
11/27/1947	RaLa shot # 94 took place on 11/27/1947 at 1755 hours. The shot involved 720 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/3/1947	RaLa shot # 95 took place on 12/3/1947 at 1735 hours. The shot involved 1056 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/10/1947	RaLa shot # 96 took place on 12/10/1947 at 1816 hours. The shot involved 706 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/18/1947	RaLa shot # 97 took place on 12/18/1947 at 1529 hours. The shot involved 619 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/29/1948	RaLa shot # 98 took place on 1/29/1948 at 1436 hours. The shot involved 1240 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/5/1948	RaLa shot # 99 took place on 2/5/1948 at 1906 hours. The shot involved 1010 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/19/1948	RaLa shot # 100 took place on 2/19/1948 at 1459 hours. The shot involved 590 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/27/1948	RaLa shot # 101 took place on 2/27/1948 at 1440 hours. The shot involved 310 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/1/1948	RaLa shot # 102 took place on 4/1/1948 at 1630 hours. The shot involved 980 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/9/1948	RaLa shot # 103 took place on 4/9/1948 at 1517 hours. The shot involved 620 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/16/1948	RaLa shot # 104 took place on 4/16/1948 at 1455 hours. The shot involved 400 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/16/1948	On June 16, 1948 there was a fire in the drybox of Room D-115. The fire was believed to have been caused by spontaneous combustion of U-235 lathe turnings.	Fire	1184	65
8/4/1948	RaLa shot # 105 took place on 8/4/1948 at 1626 hours. The shot involved 590 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/12/1948	RaLa shot # 106 took place on 8/12/1948 at 1540 hours. The shot involved 771 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SW. No activity above background was measured in the vicinity of the airstrip (now Los Alamos Airport). The roads north and south of the airstrip were checked. A film badge planted at the east end of the airstrip had only 0.003 R exposure, which is close to the limit of sensitivity for this device.	RaLa Shot	2	all
8/19/1948	RaLa shot # 107 took place on 8/19/1948 at 1625 hours. The shot involved 547 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/10/1948	RaLa shot # 108 took place on 9/10/1948 at 1721 hours. The shot involved 1735 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/14/1948	On September 14, 1948 workers cleaned out a drybox in Room 126. The material was taken to the hood in Room 119 where it was accidentally released. The room was decontaminated the following day.	User Error	3485	7
9/21/1948	RaLa shot # 109 took place on 9/21/1948 at 1543 hours. The shot involved 1006 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/28/1948	RaLa shot # 110 took place on 9/28/1948 at 1538 hours. The shot involved 487 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/7/1948	RaLa shot # 111 took place on 10/7/1948 at 1410 hours. The shot involved 362 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/14/1948	RaLa shot # 112 took place on 10/14/1948 at 1442 hours. The shot involved 205 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/21/1948	RaLa shot # 113 took place on 10/21/1948 at 1411 hours. The shot involved 123 Ci of RaLa with an explosive charge of 20 to 100 lbs.	RaLa Shot	2	all

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12/1/1948	RaLa shot # 114 took place at 1608 hours. The shot involved 480 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the south. H-1 leader T. N. White observed the cloud to drift a few points west of south and most of it appeared to settle down into Pueblo Canyon, just north of main hill road. White also saw a wisp go over Emilio Segre's old laboratory (East Gate Laboratory) at the extreme eastern end of Los Alamos Mesa. White went there with a radiation survey meter and was able to locate activity at the tip of the mesa. A few specks gave a reading that was close to the maximum with the beta shield open (20 mR/h). There was no activity a hundred feet or more to the west of the mesa tip. Following this observation, White expressed concern to D. Mueller, the leader of the Bayo Canyon experimenters, that it was undesirable to set off shots without regard to wind direction and velocity.	RaLa Shot	2	all
12/8/1948	RaLa shot # 115 took place on 12/8/1948 at 2039 hours. The shot involved 463 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/15/1948	RaLa shot # 116 took place on 12/15/1948 at 1345 hours. The shot involved 317 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E. The wind speed was 10 mph. The maximum radiation measured at distance was 0.76 mR/h at 0.25 miles.	RaLa Shot	2	all
1/25/1949	RaLa shot # 117 took place on 1/25/1949 at 405 hours. The shot involved 452 Curies of RaLa with an explosive charge of 351 to 600 lbs.	RaLa Shot	2	all
2/1/1949	RaLa shot # 118 took place on 2/1/1949 at 1630 hours. The shot involved 487 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/4/1949	RaLa shot # 119 took place on 3/4/1949 at 1359 hours. The shot involved 693 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/8/1949	RaLa shot # 120 took place on 3/8/1949 at 1413 hours. The shot involved 604 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/31/1949	RaLa shot # 121 took place on 3/31/1949 at 1647 hours. The shot involved 1096 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/20/1949	RaLa shot # 122 took place on 4/20/1949 at 1846 hours. The shot involved 422 Curies of RaLa with an explosive charge of 601 to 750 lbs. A monthly progress report of the Health Division stated, “The radioactive cloud from the Bayo shot of April 20 passed over and contaminated the area of the main gate to Los Alamos. The Fire Department washed off the most heavily contaminated section of the road shortly thereafter.” No survey report has been found.	RaLa Shot	2	all
4/27/1949	RaLa shot # 123 took place on 4/27/1949 at 2045 hours. The shot involved 1244 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/4/1949	RaLa shot # 124 took place on 5/4/1949 at 2045 hours. The shot involved 1740 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/11/1949	RaLa shot # 125 took place on 5/11/1949 at 1950 hours. The shot involved 1393 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/17/1949	RaLa shot # 126 took place on 5/17/1949 at 2030 hours. The shot involved 871 Curies of RaLa with an explosive charge of 601 to 750 lbs. A day after the last Bayo Canyon shot (#126) “activity was discovered at a point about two miles north of the Bayo firing site. The general background activity [meaning contamination] in this area was of the order of 1 mr/hr beta plus gamma ...” (presumed to be at waist height).	RaLa Shot	2	all
5/20/1949	RaLa shot # 127 took place at 1830 hours. The shot involved 588 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the ESE. The wind speed was 10 mph. The cloud from the shot crossed State Road 4 between Station 101 (a temporary guard gate at the access road to Bayo Canyon) and the McKee Trailer Camp on State Road 4. Roadblocks were established at the Main Gate and lower Bayo Canyon road junction with the main hill road. Following the shot, the blocked-off section of the road and a section running about 1 mi. east were monitored and found to be free of contamination; the roadblocks were removed. Shortly thereafter a second monitoring patrol discovered contamination on the road to the east of Frijoles Junction (the White Rock Y at the intersection of main hill road and State Road 4), which had been thought to be clean. Roadblocks were re-established at the Main Gate. The most heavily contaminated stretch of road ran about 0.75 miles east of Frijoles Junction. The highest readings were 5 to 10 mR/h 12 inches from the ground.	RaLa Shot	2	all

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6/2/1949	RaLa shot # 128 took place at 1417 hours. The shot involved 1933 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the north. The wind speed was 12 mph. The maximum radiation measured at distance was 1.5 mR/h at 1.5 miles. “Flypaper and pans [adhesive fallout collectors] distributed in Guaje Canyon previous to the shot were collected approximately two hours afterwards and were found to have no contamination. The following afternoon, however, approximately 15 mr/hr beta and gamma background [assumed at 12 inches] was found in the region over which the cloud passed.” Because “the meteorologist estimated that the cloud reached this position about five minutes after the shot,” the conclusion can be reached that the flypaper and pans were not located in the main path of the fallout.	RaLa Shot	2	all
6/6/1949	RaLa shot # 129 took place at 2206 hours. The shot involved 1630 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SE. The maximum radiation measured at distance was 1.5 mR/h at 2.5 miles. Adverse weather continued until after the shot. “An attempt was made by Health Division personnel to postpone the shot until such time that conditions were more favorable, but the decision was made to continue.” After the shot it became apparent that a portion of the main road to Los Alamos (SR 502) would become contaminated. Road blocks were placed at the west end of the airstrip, the junction of SR 4 and Sandia Canyon, and above Totavi Camp. Monitoring on the main road showed contamination from the pump house at the Bayo Canyon turnoff to 0.5 miles above Totavi, a distance of about 1.5 miles. The highest reading obtained was about 15 mR/h beta plus gamma at the main hill road and SR 4 junction. This measurement was taken at 12 inches above the road surface rather than at the usual 3 feet as was adopted later.	RaLa Shot	2	all
6/10/1949	RaLa shot # 130 took place on 6/10/1949 at 933 hours. The shot involved 1280 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NW. The wind speed was 6 mph. “Considerable effort was made by all persons involved to plan this particular operation so that the difficulties encountered in previous operations would not be present.” Continuous weather predictions were done until after the shot. “The cloud drifted off in a northwesterly direction.... Although the main portion of the cloud did not pass over any of the previously placed trays and flypaper in Guaje Canyon, a small amount of background was found seven hours later on two of them located at one edge of the cloud path.”	RaLa Shot	2	all
7/28/1949	RaLa shot # 131 took place on 7/28/1949 at 1204 hours. The shot involved 1387 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.	RaLa Shot	2	all
8/3/1949	RaLa shot # 132 took place on 8/3/1949 at 1258 hours. The shot involved 936 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.	RaLa Shot	2	all
8/9/1949	RaLa shot # 133 took place on 8/9/1949 at 957 hours. The shot involved 713 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.	RaLa Shot	2	all
8/18/1949	On June 27, 1949 there was a fire outside of TU Buildings. Fire resulted from the spontaneous combustion of TU shavings stored outside TU Building. Surrounding area was highly contaminated.	Fire	1184	169
8/31/1949	RaLa shot # 134 took place on 8/31/1949 at 1200 hours. The shot involved 715 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/14/1949	Rala shot # 135 took place on 9/14/1949 at 1202 hours. The shot involved 356 Curies of RaLa with an explosive charge of 601 to 750 lbs. Flypapers placed on North Ridge (the closest northern approach to Bayo Canyon, about 0.5 miles north, a little west, and 400 feet above of the firing site) about 50 paces apart read 3 to 4 mR/h at 1 inch with a closed-shield GM survey meter.	RaLa Shot	2	all
9/23/1949	RaLa shot # 136 took place on 9/23/1949 at 1018 hours. The shot involved 346 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SE. The wind speed was 8 mph. Nine flypapers placed on North Ridge read 0.15 to 1.0 mR/h at I inch with a closed-shield GM survey meter; the maximum reading was recorded 300 paces from the eastern-most station; the pattern appears to be skewed to the west.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
10/19/1949	RaLa shot # 137 took place on 10/19/1949 at 1007 hours. The shot involved 1385 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE. The wind speed was 15-20 mph. Flypapers placed on North Ridge read from 0.1 to 0.3 mR/h at 1 inch, measured with a closed-shield GM survey meter. The maximum flypaper reading was recorded 150 paces west of the eastern edge of the array. The ground measured 0.07 mR/h near and in good agreement with one of the flypapers, which read 0.1 mR/h. The dose rate recorder at the same location reached 1.5 mR/h as the cloud passed. A survey made the next day in Rendija Canyon about a mile east of the Sportsman's Club showed a maximum of 0.07 mR/h.	RaLa Shot	2	all
11/2/1949	RaLa shot # 138 took place at 1205 hours. The shot involved 1614 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W. The maximum radiation measured at distance was 0.8 mR/h at 2.5 miles. T. Shipman reported “an abrupt and temporary shift in the wind ... resulted in blowing the cloud ... across the Technical Area [TA-1]. As far as health and safety are concerned, no significant levels of radiation have been found. There is, however, sufficient contamination so that the background in certain counting procedures may be disturbed.” “Demonstrable contamination was found as far away as Camp May, a distance often miles' [west], but at no place were levels of contamination found to be very high.” Levels of radiation were three times background at the Base Radio Station on North Mesa. The tip of Center Mesa read 0.6 mR/h; the Chapel Apartment area on Rose Street read 0.8 mR/h; Manhattan Loop read 0.3 to 0.4 mR/h; the peak at the main gate was 1.0 mR/h gamma (1.5 mR/h, beta plus gamma). Measurements made on North Ridge were all background.	RaLa Shot	2	all
11/8/1949	RaLa shot # 139 took place on 11/8/1949 at 1243 hours. The shot involved 1064 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 7-9 mph. The cloud moved west up canyon and then northeast, missing the North Ridge flypaper array. No record of radiation measurements in surrounding areas was found.	RaLa Shot	2	all
11/14/1949	On November 14, 1949 an accident occurred between two security trucks. One truck was carrying wooden crates of steel cylinders that contained plutonium. Only one wooden crate was damaged and no contamination occurred.	Accident	3484	7
12/1/1949	In December, 1949 there was a criticality incident involving ~1 kg ^{235}U UO_2 $(NO_3)_2$ in 13.6 liters water during the manual withdrawal of two poison control rods. $3.4x10^{16}$ total fissions were involved.	Criticality	6206	all
12/8/1949	RaLa shot # 140 took place on at 1532 hours. The shot involved 2635 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 8-12 mph. The maximum radiation measured at distance was 0.6 mR/h at 2 miles. Readings from the North Ridge flypapers ranged from background to 2.5 mR/h at 1 inch measured with a closed-shield GM survey meter. The maximum reading was found on the station 50 paces from the eastern end of the nine-station array. The Point Pluto (labeled 23) recorder showed cloud passage and the collected air sample was “3X normal = 0.015 mr/ hr.” At Point Claim, the cloud passed, and a sample read “0.6 mr/hr gammas only.” Guaje Canyon was monitored the next day and a maximum of 0.2 mR/h was found "opposite Pt. Claim." Also recorded are some "GMX-5 data giving 1.2 mr/hr in Rendija Canyon N of 12 and 0.5 mr/hr N of 10."	RaLa Shot	2	all
12/16/1949	RaLa shot # 141 took place at 1739 hours. The shot involved 1539 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NW. The wind speed was 2-3 mph. The maximum reading on flypaper on North Ridge read 1 mR/h at 1 inch, measured with a closed-shield GM survey meter. The cascade impactor at Point Claim showed most of the activity to be collected on the final (filter) stage, 0.7-micron particles if density 2.5 is assumed. Another handwritten description of the December 16 shot exists and has some valuable contemporary thinking comparing RaLa with radium and some dimensional help. But, again, all discussion was aimed, as were the previous flypaper measurements, at showing whether providing an asphalt pad under the shots would reduce fallout. It apparently did. The writer calculated the effect of the worst-case (wind conditions, RaLa source size) fallout on the Guaje reservoir (a partial source of Los Alamos water at that time) to be 0.1 uCi/L or 1 mR/day for continuous intake.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
12/22/1949	RaLa shot # 142 took place at 1632 hours. The shot involved 1132 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SW. The wind speed was 3-5 mph. A “mild degree of contamination” was recorded in some parts of TA-1. No health hazard occurred; however, background activity may have been elevated enough to affect some TA-1 laboratory counting procedures.	RaLa Shot	2	all
1/13/1950	RaLa shot # 143 took place at 1248 hours. The shot involved 2065 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, SE. The wind speed was 25 mph.	RaLa Shot	2	all
1/17/1950	RaLa shot # 144 took place on 1/17/1950 at 1347 hours. The shot involved 1715 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the north and then east. The wind speed was 4-7 mph.	RaLa Shot	2	all
1/24/1950	RaLa shot # 145 took place on at 1138 hours. The shot involved 1737 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, NE. The wind speed was 25-30 mph. The cloud from the shot remained in Bayo Canyon.	RaLa Shot	2	all
1/31/1950	RaLa shot # 146 took place on 1/31/1950 at 1417 hours. The shot involved 981 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, NE. The wind speed was 9-17 mph.	RaLa Shot	2	all
3/24/1950	RaLa shot # 147 took place on 3/24/1950 at 1323 hours. The shot involved 1665 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E. The wind speed was 28-42 mph. A B-17 flight took place.	RaLa Shot	2	all
3/29/1950	RaLa shot # 148 took place at 1416 hours. The shot involved 1743 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W, WNW, and NNE. The wind speed was 2-8 mph. The maximum radiation measured at distance was 0.2 mR/h at 3 miles. “... a slight amount of contamination from fall-out was observed throughout the town site and Tech Area [TA-1]” following shot #148. It was obvious that weather conditions would not be ideal at shot time, but there was reluctance to cancel the shot for the day since weather predictions for the remainder of the week were no better. H Division authorized continuation of the operation. “The vast majority of it [the cloud] apparently moved out to the northwest toward the upper portions of Guaje Canyon. A small portion of the cloud ... took a southerly course and left detectable contamination in parts of the Los Alamos housing area (particularly in the Denver steel area), [which was the housing area closest to Bayo Canyon] and also in the Tech Area. The average levels of activity found were in the vicinity of 0.2 mr/h [Beta + gamma]... .There certainly is no reason to feel that the situation produced any health hazard whatsoever.”	RaLa Shot	2	all
4/6/1950	RaLa shot # 149 took place at 1330 hours. The shot involved 1306 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NNW, NNE. The wind speed was 18-37 mph. A B-17 flight took place.	RaLa Shot	2	all
4/20/1950	RaLa shot # 150 took place at 1431 hours. The shot involved 3334 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NW. The wind speed was 4-12 mph.	RaLa Shot	2	all
4/26/1950	Rala shot # 151 took place on 4/26/1950 at 1400 hours. The shot involved 2496 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, SE. The wind speed was 5-30 mph. The Point Myrtle weather observer was directly under the cloud as it passed over but “he experienced no contamination.”	RaLa Shot	2	all
5/12/1950	Rala shot # 152 took place on 5/12/1950 at 1359 hours. The shot involved 1355 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the S, SW. The wind speed was 10-15 mph.	RaLa Shot	2	all
5/24/1950	Rala shot # 153 took place on 5/24/1950 at 1152 hours. The shot involved 391 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 6-15 mph.	RaLa Shot	2	all
5/29/1950	On May 29, 1950 the contaminated waste disposal pit caught fire.	Fire	3483	7
6/27/1950	On June 27, 1950 -250 g of UO_3 were spilled during the transfer from a cabinet to the hood.	Contam. Event	3483	8
7/13/1950	Rala shot # 154 took place on 7/13/1950 at 1410 DST hours. The shot involved 1000 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE and N. The wind speed was 8-26 mph. The cloud motion observer's report stated “The cloud track given herein applies to only a small segment of the cloud. The bulk of the cloud seemed to dissipate without ever rising above the canyon walls.”	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
8/18/1950	On August 18, 1950 a tank containing contaminated ammonium nitrate was found leaking. The floor and area was decontaminated.	Liquid Release	3483	8
10/3/1950	On October 3, 1950 a container of PuO_2 was opened and contaminated Room 513 of CMR 12.	User Error	3483	13
2/1/1951	On February 1, 1951 there was a criticality incident involving remote control operation of 2 cylinders of U-235. The cylinders weighted 24.4 kg and 38.5 kg of 93% U-235. The 2 cylinders were in a water reflected system. There was slight oxidation of the uranium. 1017 total fissions were involved.	Criticality	1571, 6206	5, all
9/13/1951	On September 13, 1951 in Room 201 of DP West a drybox caught fire contaminating the room.	Fire	3486	7
9/29/1951	On September 29, 1951 a bottle containing 10 grams of enriched U-235 was dropped in Room 307 spilling the contents on the floor.	Contam. Event	3486	9
10/6/1951	An accident occurred on October 6, 1951 and high levels of contamination were spread in Building 52 of DP East. Everyone leaving was monitored and two cars were found to be contaminated and they were cleaned before the employees left for home.	Air Release	3486	9
10/23/1951	On October 23, 1951 a beaker containing 8 hydroxy quinoline and plutonium exploded releasing contamination into Room D-304. The filter queen located in D-304 was changed immediately and very high levels of contamination were found. The amount of Pu present in the solution was not over 1-2 milligrams.	Explosion	3486	9
3/26/1952	Rala shot # 155 took place on 3/26/1952 at 1652 hours. The shot involved 270 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 20 mph. The maximum radiation measured at distance was 0.15 mR/h at 1.5 miles. Radiation monitoring started from Point Weather westward and included the northern part of the Los Alamos housing area; 0.04 mR/h was recorded 0.1 miles from Point Weather. No activity above background was detected elsewhere on return to TA-1. A second monitor started from the Main Hill Road intersection with State Road 4 and found no activity except "0.15 mr/h in the vicinity of the first large bend in the road east of the main guard gate." No activity was detected in TA-1.	RaLa Shot	2	all
4/18/1952	On April 18, 1952 there was a criticality incident involving 92.4 kg U metal 93% ^{235}U due to computation error $1.5x10^{16}$ total fissions were involved.	Criticality	6206	all
6/16/1952	On June 16, 1952 plutonium metal ignited in an open port drybox in D-138 of D Building. The fire was quickly quenched with water.	Fire	3495	9
8/11/1952	Rala shot # 156 took place on 8/11/1952 at 1755 hours. The shot involved 2400 Ci of RaLa with an explosive charge of 101 to 200 lbs. Monitoring began from Point Weather, where activity of 0.05 mR/h was recorded. At the picnic grounds (on North Mesa), background activity was recorded. At the Sportsman's Club and 35th and Diamond Drive, less than 0.1 mR/ h was recorded. Throughout North Community, activity was less than 0.05 mR/h. The survey sheet noted "... before shot background was 0.15, after shot 0.1 mr."	RaLa Shot	2	all
8/21/1952	Rala shot # 157 took place on 8/21/1952 at 1151 hours. The shot involved 2900 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. High-volume air samplers located at Station 20 (on Puye Road), White Rock, Well #3 (just east of Guaje pumice mine), and Totavi gave the following results: 239, 689, 460, and 931 cpm, respectively. Five-stage cascade impactor data were as follows: at White Rock, all five stages—0 cpm; at Well #3, 4th stage—31 cpm, 5th stage (Whatman #41 paper)—4 cpm; Totavi, 5th stage (molecular filter)—16 cpm.	RaLa Shot	2	all
8/29/1952	Rala shot # 158 took place on 8/29/1952 at 1259 hours. The shot involved 800 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E, NE. Air samplers run in Espanola and on Puye Road showed activity in the 30- to 100-nCi range. "Good coverage was obtained on the last Bayo shot [#158] and evaluation of these data has been completed showing no hazard in any inhabited areas."	RaLa Shot	2	all
12/9/1952	On December 9, 1952 in S-104 uranium in a furnace caught fire and was contained in the furnace. Clean-up of S-104 was conducted on December 11 and 12.	Fire	3495	11
1/8/1953	On January 8, 1953 Po contamination was discovered at Pajarito Site Room 119 of Building 30. Employees of W-2 were exposed over a period of at least a week and several employee homes were contaminated. By January 13, 1953 all of W-2 and W-5 and SD houses were decontaminated. As much as 2 Ci of Po were released.	Contam. Event	124, 3492	1

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
4/3/1953	On April 3, 1953 the city dump was possibly contaminated with 125 lbs of tuballoy. 26 lbs were recovered, and the remainder was incinerated. The top layer of ashes was removed and three truck loads of dirt were placed over the contamination site.	User Error	191	53
6/10/1953	Rala shot # 159 took place on 6/10/1953 The shot was not fired, the explosive burned. Fallout trays on the main hill road and one high-volume air sampler in Guaje Canyon showed measurable activity. The monthly progress report of H-1 (the Health Physics Group) stated, "Although the east project access road [main hill road] was contaminated, the levels were low enough that they did not constitute a health hazard."	RaLa Shot	2	all
6/26/1953	On June 26, 1953 there was a small fire in a flask containing uranium hydride in D-151.	Fire	3491	4
6/29/1953	On June 29, 1953 an employee spilled approximately 40 μg of plutonium nitrate in Z Building on the floor. The area was decontaminated the following day.	Contam. Event	3491	5
8/10/1953	On August 10, 1953 a dissolver exploded releasing U-235 over the entire room.	Explosion	3491	9
8/14/1953	Rala shot # 160 took place on 8/14/1953 at 1402 hours. The shot involved 600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 10 mph.	RaLa Shot	2	all
9/10/1953	Rala shot # 161 took place on 9/10/1953 at ~1400 hours. The shot involved 250 Ci of RaLa with an explosive charge of 20 to 100 lbs.	RaLa Shot	2	all
10/9/1953	Rala shot # 162 took place on 10/9/1953 at ~1300 hours. The shot involved 215 Ci of RaLa with an explosive charge of 20 to 100 lbs.	RaLa Shot	2	all
11/12/1953	On November 12, 1953 there was an undetermined explosion in Room 501 that contaminated the room.	Explosion	3491	12
12/5/1953	On December 5, 1953 a glass furnace in a vacuum hood exploded releasing 40g of uranium.	Explosion	3491	13
1/28/1954	On January 28, 1954 a fire occurred at the contamination dump.	Fire	1184	233
2/1/1954	There have been 8 accidental prompt-critical excursions at Pajarito Site to date. The dates of the accidents are February 1951; April 1952, February 1954; July 1956; February 1957; June 1960; December 1962; May 1967. The only notable damage that occurred was in the February 1954 event. During that even there was a slight warping of the U(93) pieces, but no measurable fission-products were released. This was the second Lady Godiva accident.	Criticality	3167, 3168	18, 1
2/3/1954	On February 3, 1954 there was a criticality incident involving 53 kg U metal 93% ^{235}U due to incorrect operation at the Lady Godiva reactor. There was a slight warping of the pieces. 5.6×10^{16} total fissions were involved.	Criticality	6206	all
2/8/1954	On February 8, 1954 in CMR- 4 tritium was released when a U-tube cracked under a hood.	Air Release	3493	2
2/12/1954	Rala shot # 163 took place on 2/12/1954 at 1620 hours. The shot involved 2730 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. Two air-sampling count data sheets provided the following information: one for Puye [Road], background activity; one for Espanola, 44 net cpm; no conversion to disintegrations per minute are given.	RaLa Shot	2	all
3/8/1954	Rala shot # 164 took place on 3/8/1954 at 1615 hours. The shot involved 2000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E.	RaLa Shot	2	all
3/19/1954	Rala shot # 165 took place on 3/19/1954 at 1130 hours. The shot involved 150 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
3/29/1954	On March 29, 1954 an 800-pound pig slipped and dropped off the tailgate of a pickup dumping a white powder on the truck and the dock. The area became contaminated with Sr-90 and was decontaminated. No one was allowed to wear contaminated clothing home.	User Error	3493	13
4/14/1954	Rala shot # 166 took place on 4/14/1954 at 1345 hours. The shot involved 190 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. No radiation was detected. Fallout was monitored starting at the main gate. Otowi ruins. White Rock, Mora's Castle (also known as the Duchess' Castle), Otowi Bridge, and 5 miles up Espanola highway (State Road 5) were surveyed from the main hill road. No readings above background were obtained.	RaLa Shot	2	all
4/19/1954	On April 19, 1954 a mixture containing 5 milligrams of americium exploded.	Explosion	3493	14

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/2/1954	Glass tube holding plutonium covered wire broke releasing Pu at Y Building on July 2, 1954.	Equipment Malfunction	2364	3
7/31/1954	RaLa shot # 167 took place at 1605 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 101 to 200 lbs. The maximum radiation measured at distance was 1.5 mR/h at 2.25 miles. The cloud started to the NE with very little velocity; the wind shifted shortly after the shot took place and spread fallout to the SE and S. A rain shower occurred in Bayo Canyon 35 minutes after the shot. Activity was detected between SR 4 and the Sandia Canyon guard station, one-half mile east of SR 4. Measurements in White Rock showed background activity. The next evening, 1 mR/h was measured at Otowi ruins. A hand-drawn fallout map was made, from which D. Meyer deduces, "Fallout area was approximately 4 square miles... average reading was 0.5 mr/hr with shield open at waist level. This equals to about 1 mr/hr at contact shield open or 0.15 mr/hr shield closed at 6" from ground."	RaLa Shot	2	all
8/5/1954	RaLa shot # 168 took place at 1830 hours. The shot involved 1500 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 0 mph. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles; 0.15 mR/h at 12 miles. The team made background readings in Rendija Canyon to the north and northeast several hours before the shot, finding elevated background activity from the previous shot (#167). After the shot, a counterclockwise survey began, reaching Totavi at 1845. The team returned up Guaje Canyon, encountering new fallout measuring 0.4 mR/h at the pumice mine (background in the morning was 0.04 mR/h) but found no further increase over the earlier background activity as far as the junction of Guaje and Rendija canyons. The team returned down Guaje Canyon and proceeded toward Espanola, encountering activity 4.5 miles south of Espanola with a maximum of 0.2 mR/h at the Puye Road turnoff. Activity was 0.15 mR/h at Santa Clara Pueblo and 0.1 to 0.15 mR/h in Espanola. The team returned to Puye Road the next morning and found slightly lower readings than the day before.	RaLa Shot	2	all
9/9/1954	RaLa shot # 169 took place at 1518 hours. The shot involved 265 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the S. The wind speed was 1 mph. The maximum radiation measured at distance 0.1 mR/h at 1 mile; 0.45 mR/hr at 2 miles 0.3 mR/hr at 2.5 miles; 0.18 mR/hr at 4 miles. The survey team passed the Los Alamos airstrip at 1538, where fallout was encountered; a maximum of 1.1 mR/h was recorded 1.4 miles east of the airport. Team members completed the survey including west up Guaje Canyon; all readings were background, which varied between 0.03 and 0.05 mR/h. More readings were taken the next day on other roads further south; a fallout map was prepared showing a relatively narrow fall-out pattern to the south-southwest over laboratory property, crossing Sandia Canyon, 0.45 mr/hr, and other east-west roads in the laboratory area.	RaLa Shot	2	all
9/16/1954	RaLa shot # 170 took place at 1458 hours. The shot involved 300 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NW. No radiation was detected. The team started a clockwise survey from TA-1 before 1500 and continued on to Espanola and Riverside (east side of Espanola). No fallout above background was detected. A map was made.	RaLa Shot	2	all
10/21/1954	An electrode broke within a flask causing tritium to be released into the hood in Room 220 of HRL Building on October 21, 1954.	Equipment Malfunction	2368	3
10/24/1954	U-235 material ignited spontaneously in the sigma vault on October 24, 1954.	Fire	2368	3
11/4/1954	RaLa shot # 171 took place at 1335 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 7 mph. The maximum radiation measured at distance was 0.3 mR/h at 1.5 miles. The team started a clockwise perimeter survey from TA-1 at 1600; background activity was 0.03 mR/h. All readings were background to State Road 4. The team returned up Guaje/Rendija Canyons and measured 0.3 mR/h for about 0.5 miles beginning 1.5 miles east of the Sportsman's Club. Apparently the activity was missed or had not yet arrived on the first pass.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
11/16/1954	RaLa shot # 172 took place at 1500 hours. The shot involved 2440 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.3 mR/h 3.5 miles; 0.2 mR/h at 5 miles. The team began a clockwise perimeter survey at 1538 and encountered fallout in Guaje Canyon about 1.1 mile west of State Road 4 with a maximum of 0.2 mR/h at 1 mile west of State Roads 4. The team checked Totavi, background, and then started north on the Espanola Road (State Road 5). Very low readings (0.04 to 0.075 mR/hr) were found in the first 1.9 miles north of State Road 4 and 5 junction. The team returned west up Guaje Canyon; the measured maximum of 0.3 mR/h was again found 1 mile up canyon, essentially the same as before. Background seemed quite variable on this survey.	RaLa Shot	2	all
12/2/1954	RaLa shot # 173 took place at 1645 hours. The shot involved 1585 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNW. The maximum radiation measured at distance was 1 mR/h at 1.5 miles. Team members began a clockwise survey from TA-1 before 1730; background was 0.04 to 0.05 mR/h. They encountered fallout at the Sportsman's Club, which continued for 2.5 miles; the maximum reading of 1.0 mR/h was recorded 0.5 miles west of the Rendija Canyon gate.	RaLa Shot	2	all
12/7/1954	On December 7, 1954 Room 5006 of CMR Building was found to be highly contaminated. The exhaust fan for this room is not filtered, contamination was probably released into the environment.	Air Release	3493	21
12/9/1954	RaLa shot # 174 took place on 12/9/1954 at 1604 hours. The shot involved 500 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
12/30/1954	RaLa shot # 175 took place on 12/30/1954 at 1445 hours. The shot involved 320 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. No radiation was detected. The team surveyed Rendija and Guaje canyons. No readings above background were found, though spurious readings were encountered between the Sportsman's Club and the Rendija Canyon gate. These readings were explained as residual from previous shots. Although we have no fallout data on the previous shot, it seems unlikely that this explanation is valid because of the decay time.	RaLa Shot	2	all
1/1/1955	On one occasion during the year it was suspected that the city water line was contaminated due to corrosion. Tests did not detect contamination, but the repairs were made.	Liquid Release	3053	53
1/6/1955	RaLa shot # 176 took place on 1/6/1955 at 1415 hours. The shot involved 134 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles. A clockwise perimeter survey monitored Rendija and Guaje canyons as far as the well-drilling site below the Guaje pumice mine. Readings were 2 times background (0.07 mR/h) from the Rendija Canyon gate to 0.6 miles east of the gate. All other readings were background.	RaLa Shot	2	all
1/12/1955	RaLa shot # 177 took place on 1/12/1955 at 1415 hours. The shot involved 180 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The maximum radiation measured at distance (mR/h) was 0.12 mR/h at 1.3 miles. Two surveys were made in Rendija and Guaje canyons to about I mile past the pumice mine. Twice background, 0.07 mR/h, was measured from the Rendija Canyon gate about 0.6 miles east. All other readings were background.	RaLa Shot	2	all
1/13/1955	On January 13, 1955 a ampule of americium curium mixture exploded spreading contamination on two workers. The workers rinsed off in a sink and drove to the hospital. The route to the hospital and the vehicle was decontaminated.	Explosion	3489	4
3/9/1955	Uranium was released into the hood of Room 121 at TA-46 on March 9, 1954.	Air Release	2383	2
3/17/1955	RaLa shot # 178 took place on 3/17/1955 at 1255 hours. The shot involved 3160 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the NE. No radiation was detected. A northern perimeter survey was done in Rendija and Guaje canyons, down and back. All readings showed background activity.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/23/1955	RaLa shot # 179 took place at 1315 hours. The shot involved 2260 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 8-15 mph. The maximum radiation measured at distance was 0.3 mR/h at 3 miles. A clockwise perimeter survey starting about 1400 found only background activity in Rendija and Guaje canyons. The team encountered fallout just east of Totavi (0.1 mR/h), which increased through Totavi and reached 0.3 mR/h at 0.2 miles west of Totavi and continued for 0.3 miles. The team retraced its route to check further east of Totavi to Otowi Bridge; readings showed background activity. Activity at the White Rock Y (intersection of main hill road and State Road 4) measured 0.1 mR/h; measurements taken towards and in White Rock were all background. A reading of 1 mR/h was recorded at Otowi ruins by another team. A rough map was drawn.	RaLa Shot	2	all
3/30/1955	RaLa shot # 180 took place at 1315 hours. The shot involved 2642 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 6-10 mph. The maximum radiation measured at distance was 0.6 mR/h at 2 miles. The general background activity in the Los Alamos area was elevated because of fallout from the Nevada Test Site (NTS). Background activity of 0.5 mR/h was measured in TA-1, 0.1 to 0.2 mR/h on State Road 4 to Totavi, and 0.1 to 0.15 mR/h on North and Tank (Barranca) mesas. The Guaje-Rendija survey passed the Sportsman's Club at 1415, where the background due to NTS fallout was 0.3 mR/h. The team found readings in excess of this background and attributed these readings to activity from this shot for about 1 mile west of the Guaje pumice mine to the mine.	RaLa Shot	2	all
4/7/1955	RaLa shot # 181 took place at 1522 hours. The shot involved 2080 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 5 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.2 miles. The team stalled the Rendija and Guaje canyons survey from TA-1 at 1600; encountering activity 1.9 miles past the Sportsman's Club. This activity continued for about 1 mile, with a maximum of 0.07 mR/h measured 0.1 miles east of the Rendija Canyon gate to 0.5 miles past the Guaje pumice mine. Here the team turned around and retraced its path. At 1654, the reading at the Sportsman's Club had increased to 0.075 mR/h. It was noted that “residual readings of 0.04 to 0.06 mr/hr from NTS test fallout a week ago prevailed throughout the survey area.”	RaLa Shot	2	all
4/22/1955	RaLa shot # 182 took place at 1810 hours. The shot involved 700 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.4 mR/h at 1.5 miles. The team began to survey Rendija and Guaje canyons at 1845; background activity was 0.03 mR/h. Activity was encountered 2.3 miles past the Sportsman's Club and continued for about 1 mile, with a maximum of 0.4 mR/h 2.3 miles past the Sportsman's Club.	RaLa Shot	2	all
4/28/1955	RaLa shot # 183 took place at 1515 hours. The shot involved 3200 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
5/5/1955	RaLa shot # 184 took place at 1540 hours. The shot involved 2560 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. A team surveying Rendija and Guaje canyons passed the Sportsman's Club at 1625; background was 0.02 to 0.04 mR/h. The team encountered fallout 2 miles further at Rendija Canyon gate; fallout continued to 0.7 miles past the Guaje pumice mine. A maximum reading of 0.2 mR/h was measured 0.4 miles east of the junction of Rendija and Guaje canyons. All other readings were background.	RaLa Shot	2	all
5/12/1955	On May 12, 1955 a small furnace erupted releasing an unknown quantity estimated at less than one kilogram of uranium in Room 102 of Sigma Building.	Explosion	2374	6
5/12/1955	There was a tuballoy fire in Sigma Building, Room 103 on May 12, 1955.	Fire	3489	10
5/12/1955	RaLa shot # 185 took place at 1625 hours. The shot involved 2100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph. No radiation was detected. Rendija and Guaje canyons were surveyed. All readings showed background activity.	RaLa Shot	2	all
5/20/1955	RaLa shot # 186 took place at 1845 hours. The shot involved 1470 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.5 mR/h at 1.5 miles. Rendija and Guaje canyons were surveyed. Activity at the Rendija Canyon gate was 0.18 mR/h. At 0.2 miles east of the Rendija Canyon gate, the reading was 0.5 mR/h. All other readings were 0.08 to 0.1 mR/h.	RaLa Shot	2	all

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5/26/1955	RaLa shot # 187 took place at 1154 hours. The shot involved 520 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 4-7 mph. The maximum radiation measured at distance was 1 mR/hr at 1.2 miles. Rendija and Guaje canyons were surveyed. All readings were background, which was noted as "elevated from previous shot." A reading of 1 mR/h was recorded at Otowi ruins.	RaLa Shot	2	all
6/2/1955	RaLa shot # 188 took place at 1345 hours. The shot involved 490 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph. The maximum radiation measured at distance was 0.16 mR/h at 1.5 miles. Rendija and Guaje canyons were surveyed. The path of fallout extended 0.3 miles west of the Rendija Canyon gate to 0.8 miles east. The highest reading was 0.16 mR/h. D. Meyer's handwritten note says, "no fallout found"; we assume he interpreted the fallout as resulting from previous shot(s).	RaLa Shot	2	all
7/21/1955	On July 21, 1955 some normal uranium caught fire in Room 1131.	Fire	1184	466
8/3/1955	On August 3, 1955 a mock fission polonium source containing 25.2 curies of Po exploded in the basement of the Physics Building. Contamination was spread through out the Physics Building.	Explosion	2377	3
8/19/1955	On August 19, 1955 an employee dropped a test tube containing one gram of normal uranium in Wing 2 of CMR Building.	User Error	3489	14
9/6/1955	On September 6, 1955 a radiation contamination incident occurred in Room 1 of ML Building.	Contam. Event	3489	14
9/16/1955	RaLa shot # 189 took place at 1455 hours. The shot involved 2600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. The team began a clockwise perimeter survey from Point Weather at 1500; background was 0.03 mR/h. The highest reading of 0.2 mR/h was measured at Point Weather (which must have been direct radiation from the firing pad, reading 65 R/h at a meter above the firing pad after the shot). Fallout was encountered in Guaje Canyon at the pumice mine, continuing for 1.2 miles with a maximum of 0.2 mR/h recorded 0.3 miles east of the pumice mine.	RaLa Shot	2	all
9/28/1955	RaLa shot # 190 took place at 1631 hours. The shot involved 2600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph.	RaLa Shot	2	all
10/7/1955	RaLa shot # 191 took place at 1515 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was light. The maximum radiation measured at distance was 2 mR/h at 1.5 miles. The team began a clockwise survey from TA-1 at 1555; background was 0.03 mR/h. Fallout was encountered 1.4 miles east of the Sportsman's Club, which continued about 0.6 miles down Rendija Canyon. The team continued west up Guaje Canyon, encountering fallout 0.2 miles west up canyon; this fallout continued for 1.1 miles with a peak of 1 mR/h recorded 0.8 miles west up canyon. The team completed the survey down Guaje Canyon and returned through Totavi. All activity was background.	RaLa Shot	2	all
10/19/1955	RaLa shot # 192 took place at 1720 hours. The shot involved 2000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.5 mR/h 6 miles. The team began a counterclockwise survey past the main gate at 1800; background was 0.01 to 0.03 mR/h. The team encountered activity 0.4 miles north on Espanola Road (State Road 5), which continued for about 3 miles. A maximum reading of 0.5 mR/h was measured. The team surveyed around the gravel pits near the Rio Grande, south of Pajarito Village; a maximum of 2 mR/h probably was influenced by several particles, judging from the lower readings on State Road 5. One particle read 1.4 mR/h beta plus gamma at "contact," and another read 11 mR/h gamma at 6 inches, using a Cutie Pie ion-chamber survey instrument. Later, photomicrographs, autoradiographs, and activity determinations of two particles were made; each particle measured over 300 microns in the longest dimension.	RaLa Shot	2	all

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10/26/1955	RaLa shot # 193 took place at 1630 hours. The shot involved 3987 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 1 mR/h at 3 miles; 0.1 mR/h at 10 miles. The team began a counterclockwise perimeter survey from TA-1 at 1725; background was 0.03 mR/h. All readings showed background activity until 5.4 miles past Totavi on Espanola Road (State Road 5), where fallout was encountered that continued to Santa Clara Pueblo; a maximum of 0.15 mR/h was found at Puye Road. The team returned up Guaje Canyon, encountering fallout 1.8 miles west up canyon, which continued for about 1 mile. The maximum reading of 1.0 mR/h was recorded 1 mile east of the Guaje pumice mine. The remainder of the perimeter survey readings showed background activity.	RaLa Shot	2	all
11/3/1955	RaLa shot # 194 took place at 1605 hours. The shot involved 3500 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was 7 mph. The maximum radiation measured at distance was 1.6 mR/h at 1.5 miles; 3.0 mR/h at 2 miles; 0.2 mR/h at 5 miles. The team began a clockwise perimeter survey from TA-1 at 1645; background activity was 0.04 mR/h. Fallout was encountered 2.1 miles past the Sportsman's Club and continued for about 1 mile. A maximum reading of 1.6 mR/h was recorded 0.3 miles further on. The team went west up Guaje Canyon, encountering fallout 0.3 miles up canyon. The fallout continued for about 1 mile, with a maximum of 3.0 mR/h recorded between 0.6 to 0.7 miles west up canyon. The remainder of the perimeter survey was completed down Guaje Canyon, through Totavi, and back to TA-1. All readings showed background activity. The following morning Puye Road was surveyed, with readings fluctuating between 0.1 and 0.2 mR/h from the Espanola Road (State Road 5) to the Puye Ruins.	RaLa Shot	2	all
11/17/1955	RaLa shot # 195 took place at 1354 hours. The shot involved 1600 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 8-10 mph. The maximum radiation measured at distance was 0.65 mR/h at 1.5 miles; 0.3 mR/h at 2 miles. The team began a clockwise perimeter survey from TA-1 at 1430; background was 0.03 mR/h. Fallout was encountered 0.7 miles past the Sportsman's Club and continued for 1.4 miles, with a maximum of 0.65 mR/h recorded 1.7 miles past the Sportsman's Club. The team surveyed west up Guaje Canyon; a maximum of 0.3 mR/h was recorded 2 miles up the canyon.	RaLa Shot	2	all
11/29/1955	RaLa shot # 196 took place at 1535 hours. The shot involved 780 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 5-7 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles; 0.4 mR/h at 2 miles. The team began a clockwise perimeter survey from TA-1 at 1625; background was 0.03 mR/h. Fallout was encountered at the Rendija Canyon gate and continued for 0.8 miles, with a maximum of 0.7 mR/h measured 0.4 miles beyond. The fallout pattern also crossed upper Guaje Canyon with a maximum of 0.4 mR/h about a mile west up canyon. Above-background readings were recorded for about 3 miles to Guaje Canyon gate, where the team completed the survey through lower Rendija and Guaje canyons to Totavi. Only background activity was found.	RaLa Shot	2	all
1/27/1956	RaLa shot # 197 took place at 1443 hours. The shot involved 1300 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. No radiation was detected. The team began a special survey from TA-1 at 1500; background activity was 0.05 mR/h. Since the cloud remained in Bayo Canyon, the team surveyed only in the eastern part of the canyon to the Otowi ruins, recording a maximum of 0.4 mR/h at 0.3 miles west up Bayo Canyon from State Road 4. A rough sketch was made.	RaLa Shot	2	all
2/1/1956	In 1956 approximately 1 Ci of Sr was released into Mortandad canyon when a line broke on a full tank of waste.	Liquid Release	1733	20
2/11/1956	During the week of February 11, 1956 a pipe carrying water near Ten Site developed a leak releasing 35,000 gallons of contaminated water into Mortandad canyon.	Liquid Release	2382	2
2/21/1956	RaLa shot # 198 took place at 1805 hours. The shot involved 2100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.7 mR/h at 3 miles. The team began a clockwise perimeter survey from TA-1 at 1830; background activity was 0.05 mR/h. The picnic grounds and stables (on North Mesa), and Tank Mesa (Barranca Mesa) were surveyed; background activity was recorded. Fallout was encountered 1.1 miles past the Guaje pumice mine and continued for 1.3 miles with a maximum of 0.7 mR/h recorded 0.6 miles past the mine.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/1/1956	RaLa shot # 199 took place at 1540 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 7 mph. The maximum radiation measured at distance was 1.0 mR/h at 2 miles. The team began a counterclockwise perimeter survey from TA-1 at 1630; the background activity was 0.03 to 0.05 mR/h. Fallout was encountered in Guaje Canyon just east of the pumice mine and continued for almost 3 miles. A maximum of 1.0 mR/h was recorded about 0.2 miles past the Rendija/Guaje Y. The team returned west up Rendija Canyon, measuring 0.1 to 0.2 mR/h for about 0.8 miles. Tank Mesa (Barranca Mesa) and North Mesa were surveyed; only background activity was noted.	RaLa Shot	2	all
3/9/1956	On March 9, 1956 a spill of uranium flowed into the bottom of the furnace in Room 21 of the Sigma Building.	Contam. Event	2383	2
3/9/1956	RaLa shot # 200 took place at 1730 hours. The shot involved 435 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The wind speed was 8-12 mph.	RaLa Shot	2	all
3/14/1956	RaLa shot # 201 took place at 1345 hours. The shot involved 560 Ci of RaLa with an explosive charge of 101 to 200 lbs. No radiation was detected. The team began a counterclockwise perimeter survey from TA-1 at 1408; the background activity was 0.05 mR/h. All measurements were background.	RaLa Shot	2	all
3/22/1956	RaLa shot # 202 took place at 1330 hours. The shot involved 389 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The maximum radiation measured at distance was 0.15 mR/h at 2.2 miles. The survey team left TA-1 at 1420; background radiation was 0.03 mR/h. A reading of 0.04 mR/h was recorded at the picnic grounds (on North Mesa), 0.15 mR/h at “overlook of Bayo” [tip of Otowi Mesa, called also “North Ridge”—probably direct radiation from the firing pad, which was reading 40 R/h waist high above the pad shortly after the shot]. Readings on the “mesa north of previous measurement (0.15 mr/hr),” (Deer Trap Mesa, northeastern-most Barranca Mesa) were background. At 2.7 miles east of the Sportsman's Club, fallout of 0.12 mR/h was encountered. At 2.9 miles, fallout was 0.15 mR/h, and at Booster #1 (near Guaje/Rendija Y) it was 0.08 mR/h. About 0.5 miles up Guaje Canyon, fallout was 0.13 mR/h.	RaLa Shot	2	all
4/7/1956	RaLa shot # 203 took place at 1730 hours. The shot involved 1520 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the ESE. The wind speed was 8 mph. The maximum radiation measured at distance was 1.0 mR/h at 4 miles. The team departed TA-1 at 1812; background activity was 0.03 mR/h. Background activity was measured until the team reached the “tip of Tank Mesa [Barranca Mesa],” where the reading was 0.3 mR/h (direct radiation from the firing pad may have affected this measurement). A clockwise perimeter survey was continued. Background activity was recorded until the Guaje Canyon road junction with State Road 4; at that point, the reading was 0.10 mR/h. Background activity was recorded further east to the junction of State Roads 4 and 5. Readings increased to 1.0 mR/h at Roy's Service Station (Totavi); continuing 0.6 miles west, only background activity was found to TA-1. The cloud did not rise above the Bayo Canyon walls and apparently followed the canyon	RaLa Shot	2	all
4/12/1956	RaLa shot # 204 took place at 1455 hours. The shot involved 3740 Ci of Rala with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 12 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles; 0.07 mR/h at 5.5 miles. The team began a clockwise survey from TA-1 at 1555; background activity was 0.03 mR/h. Down Rendija Canyon, 2 miles past the Sportsman's Club, the team encountered fallout measuring 0.05 mR/h, with a maximum of 0.7 mR/h recorded 2.5 miles beyond. Activity slowly decreased to background activity within half a mile. The team continued down Guaje Canyon to State Road 4 and north to Puye Road junction and then west, encountering 0.07 mR/h 6 to 6.4 miles west on Puye Road, essentially directly in line with the previous encounter in Guaje Canyon. The next morning the team monitored in Espanola, Riverside, and Fairview (areas east and north of Espanola); only background activity was detected.	RaLa Shot	2	all
4/20/1956	RaLa shot # 205 took place at 1436 hours. The shot involved 3200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was 8 mph. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles. The team began a clockwise survey from TA-1 at 1506; background activity was 0.03 mR/h. Team members encountered fallout about 0.7 miles past the Sportsman's Club. Activity was 0.09 mR/h, falling to 0.05 mR/h in the next 0.3 miles. Only background activity was found at Booster #1 (3 miles east past the Sportsman's Club) and for 2.3 miles west up Guaje Canyon. At 2.3 miles, fallout was encountered, which increased to a broad maximum of 0.4 mR/h for 0.4 miles, continued at this level for 0.4 miles, and then decreased to 0.15 mR/h at the Guaje Canyon gate.	RaLa Shot	2	all

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4/26/1956	RaLa shot # 206 took place at 1140 hours. The shot involved 2195 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 5 mph. No radiation was detected. The survey team left TA-1 at 1223; background activity was 0.03 mR/h. The team made the complete perimeter survey and found no readings above background. The cloud was observed to start to the north and then spread east along the canyon rim.	RaLa Shot	2	all
5/10/1956	RaLa shot # 207 took place at 1145 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 20 to 100 lbs. No radiation was detected. The survey team left TA-1 at 1310; background activity was 0.03 mR/h. The perimeter survey was completed with no readings above background recorded.	RaLa Shot	2	all
5/21/1956	RaLa shot # 208 took place at 1300 hours. The shot involved 4,000 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NW. The maximum radiation measured at distance was 0.16 mR/h at 1.5 miles. The team began a clockwise perimeter survey from the Administration Building (TA-3, SM-43) at 1340 (note the new starting point); background activity was 0.03 mR/h. Fallout was encountered from 0.9 to 1.2 miles east of the Sportsman's Club, and the maximum activity was 0.15 mR/h beyond the Sportsman's Club. The team completed the survey route, finding only background activity. The cloud was observed to move to the south Bayo Canyon wall and then rise and move north.	RaLa Shot	2	all
5/25/1956	RaLa shot # 209 took place at 1155 hours. The shot involved 4195 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.8 mR/h at 1.5 miles; 1.2 mR/h at 2 miles. The survey team left Point Weather at 1200 (only 5 minutes after the shot) and immediately measured 13 mR/h (probably direct radiation from the cloud, not fallout). On the continuing clockwise perimeter survey, fallout (0.1 mR/h) was encountered 1.4 miles east of the Sportsman's Club and continued above background with peaks of 0.8 mR/h at the Barranca (Rendija) gate and 1.2 mR/h 0.4 miles west up Guaje Canyon. The remainder of the survey found no activity above background.	RaLa Shot	2	all
6/7/1956	RaLa shot # 210 took place at 1455 hours. The shot involved 2907 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles. The team left the Administration Building (SM-43) at 1416; background activity was 0.03 mR/h to Point Weather, where the reading was 0.07 mR/h (probably a direct reading from the firing pad). Fallout was encountered 0.6 miles past the Sportsman's Club, with a maximum of 0.7 mR/h recorded 1.8 miles east. It continued above background for another 0.6 miles. The team completed surveying the rest of the perimeter, encountering only background activity.	RaLa Shot	2	all
6/14/1956	RaLa shot # 211 took place at 1305 hours. The shot involved 1840 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the WSW. The wind speed was light (5) mph. No radiation was detected. The survey team left the Administration Building (SM-43) at 1315; background activity was 0.03 mR/h; activity at Point Weather was 0.07 mR/h. Only background activity was encountered on the perimeter survey. The section of State Road 4 road toward White Rock was also checked and background found.	RaLa Shot	2	all
7/3/1956	On July 3, 1956 there was a criticality incident involving 58 kg U in the form of 93% U-235 as 2- and 5-mil foils. Changes were made in the reflector and graphite moderator and criticality was reached too quickly. 3.2×10^{16} total fissions were involved.	Criticality	6206	all
10/5/1956	RaLa shot # 212 took place at 1428 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NW and N. The wind speed was 13 mph. The maximum radiation measured at distance was 1.3 mR/h at 1.5 miles; 1.3 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1555; background activity was 0.03 mR/h; activity at Point Weather was 0.5 mR/h. Fallout was encountered 1.3 miles east of the Sportsman's Club and continued for 3.1 miles, with a peak between 1.0 and 1.3 mR/h recorded 2.1 miles east of the Club. Fallout also crossed Guaje Canyon beginning 0.5 miles west up Guaje Canyon and continuing above background for 2.1 miles. A maximum reading of 1.3 mR/h was recorded 1.l miles west up canyon.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
10/16/1956	RaLa shot # 213 took place at 1534 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 5 mph. The maximum radiation measured at distance was 0.8 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1605; background activity was 0.03 mR/h. Fallout was encountered 2.4 miles east of the Sportsman's Club (0.1 mR/h) and 0.8 miles west up Guaje Canyon (0.8 mR/h). During the remainder of the clockwise perimeter survey, only background activity was detected.	RaLa Shot	2	all
10/23/1956	On October 23, 1956; 100 mg of plutonium hexafluoride exploded in a drybox in Room 5122 of CMF 2. The material entered the exhaust system of the drybox and was vented into the filter tower for Wing 5. The filter tower filters were changed and monitored for contamination.	Explosion	4055	6
10/27/1956	RaLa shot # 214 took place at 1420 hours. The shot involved 300 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 10 mph. The maximum radiation measured at distance was 0.5 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1501; background activity was 0.04 mR/h. Fallout was encountered 1.3 miles east past the Sportsman's Club, with a peak of 0.5 mR/h occurring 0.5 miles further on. The peak reading was caused by a one-foot-square contaminated area measuring 6 mR/h at 6 inches (probably one or more particles).	RaLa Shot	2	all
11/1/1956	RaLa shot # 215 took place at 1023 hours. The shot involved 200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 9 mph. The maximum radiation measured at distance was 0.3 mR/h at 1.5 miles; 0.15 mR/h at 2.3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1100; background activity was 0.03 mR/h. Fallout was encountered 0.5 miles east of the Sportsman's Club, with a peak of 0.3 mR/h occurring 1.7 miles past the Sportsman's Club. Above-background readings continued to the Rendija/Guaje canyons junction and then increased west up Guaje Canyon, with a peak of 1.5 mR/h occurring 1.8 miles up the canyon and continuing above background for about 1 mile. The team completed the perimeter survey down Guaje Canyon to Highway 4 and returned to the Administration Building; only background activity was detected.	RaLa Shot	2	all
12/5/1956	RaLa shot # 216 took place at 1500 hours. The shot involved 800 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 17 mph. The maximum radiation measured at distance was 1.0 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1515; background activity was 0.03 mR/h. Fallout was encountered 1 mile past the Sportsman's Club and continued for 0.8 miles, with a peak of 1.0 mR/h occurring 1.4 miles past the Sportsman's Club. The perimeter survey was completed with positive readings recorded 1 mile east of the main gate. Peak activity of 0.4 mR/h occurred at the entrance to the East Gate Lab. No explanation was offered for these later readings, which are in the opposite direction from which the main cloud was detected. Operations at the East Gate Laboratory are suspected (see shots #238, 240, and 242).	RaLa Shot	2	all
12/20/1956	RaLa shot # 217 took place at 1450 hours. The shot involved 225 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the W and SW. The wind speed was 3 mph. The maximum radiation measured at distance was 1 mR/h at 0.6 miles; 0.3 mR/h at 1 mile; 0.5 mR/h at 2 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1510; background activity was 0.05 mR/h. A reading of 0.3 mR/h was recorded at the dump site near the Los Alamos Airport. The team completed the perimeter survey; all readings showed only background activity. A town site survey began at 1700; a peak of 0.15 mR/h was recorded at the eastern end of Manhattan Loop (eastern residential area). Activity up to 0.075 mR/h was recorded at the DP Road trailer court (south of the airport). At 0.1 miles west of Point Weather, activity from 1 mR/h to 0.5 mR/h was recorded to the ballpark (on North Mesa), where background activity was measured.	RaLa Shot	2	all
2/7/1957	On February 7, 1957 an explosion and fire occurred in the pure metal drybox in Room 406 of DP West. The only contamination found was on the outside of the air intake filters.	Explosion	4056	16
2/8/1957	On February 8, 1957 tinners disconnected the exhaust duct on the wooden drybox line in Room 500. Highly contaminated dust spread throughout the south part of the room.	Air Release	3490	11

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
2/12/1957	At 3 pm on February 12, 1957 the Godiva assembly located at Kiva 2 at Pajarito Site went supercritical. Filters in the heating system were found to be highly contaminated. The exhaust system was not running at the time of the incident. This incident involved 54 kg U metal, which was 93% U-235. There was warping and oxidation near melting close to center. 1.2×10^{17} total fissions were involved.	Criticality	2817, 6206	1-2, all
3/7/1957	On March 7, 1957 a worker in Room 2125 Wing 2 of CMR Building was working with 20 grams of plutonium in a glovebox when they noticed that there was a leak in the glove.	Air Release	3490	19
3/16/1957	RaLa shot # 218 took place at 1245 hours. The shot involved 2140 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 15 mph.	RaLa Shot	2	all
3/27/1957	On March 27, 1957 an explosion occurred in the machine lathe drybox in Room 500. The operator of the lathe was highly contaminated. After showering no contamination was detected.	Explosion	3490	23
3/29/1957	RaLa shot # 219 took place at 1250 hours. The shot involved 3079 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. The wind speed was 6 mph. The maximum radiation measured at distance was 0.1 mR/h at 3 miles; 0.07 mR/h at 7 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1330; background activity was 0.03 mR/h. A reading of 0.1 mR/h was recorded at the stables (on North Mesa), but it was questioned on the survey sheet as not being reasonable, probably because the cloud was reported to have gone to the east. Fallout of 0.07 mR/h was encountered in Guaje Canyon 0.7 miles past the pumice mine, continuing for about 0.5 miles, with a peak of 0.1 mR/hr halfway between. Activity between 0.5 and 0.07 mR/h was recorded north on State Road 5, 3.2 miles from the junction.	RaLa Shot	2	all
4/17/1957	RaLa shot # 220 took place at 1630 hours. The shot involved 3249 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The wind speed was 12 mph. The maximum radiation measured at distance was 0.4 mR/h at 4.5 miles. The team left the Administration Building (SM-43) at 1650; background activity was 0.03 mR/h. During the counterclockwise perimeter survey, fallout (0.04 mR/h) was encountered at the junction of the Main Hill Road/ White Rock cutoff. It increased to a maximum of 0.4 mR/h at 0.3 miles before the junction of Guaje Canyon and State Road 4. At Otowi Bridge, activity was 0.08 mR/h; at the Espanola Highway (State Road 5) to Puye Road, it was 0.08 to 0.09 mR/h for 3 miles. At the entrance to Guaje Canyon, activity was 0.2 mR/h and persisted to the Guaje pumice mine, where the 0.08 mR/h reading was attributed to contamination on the vehicle since the reading continued at this level until the team returned to the Administration Building. Weather observations confirmed that the cloud did not rise above the canyon walls to reach the southwest winds.	RaLa Shot	2	all
5/9/1957	RaLa shot # 221 took place at 1600 hours. The shot involved 1000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 7 mph. No radiation was detected. The team began a clockwise survey from Administration Building (SM-43) at 1630; background activity was 0.04 mR/h. A clockwise perimeter survey was completed that included Puye Road; no measurable fallout was detected. Weather observations of the cloud support these findings. The cloud remained in Bayo Canyon.	RaLa Shot	2	all
6/5/1957	There was a fire in the back of a contaminated dump truck on June 5, 1957.	Fire	3490	23
6/13/1957	On June 13, 1957 there was a contamination incident in Room 513 of DP West. The contamination occurred during the cleaning out of a Lucite casting tunnel.	Contam. Event	3490	49
6/20/1957	RaLa shot # 222 took place at 1540 hours. The shot involved 1000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 12 mph. No radiation was detected. The team left the Administration Building (SM-43) at 1625; background was 0.03 mR/h. A counterclockwise survey included the Puye pumice mine; the survey team returned through Guaje Canyon. The recorded instrument readings fluctuated between 0.02 and 0.05 mR/h but were considered negative. Weather observations confirmed that the cloud remained in the canyon.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/10/1957	RaLa shot # 223 took place at 1625 hours. The shot involved 2257 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 8 mph. The maximum radiation measured at distance was 0.6 mR/h at 1.5 miles. The team began a clockwise survey from Administration Building (SM-43) at 1640; background activity was 0.05 mR/h. Fallout was encountered 0.4 miles east past the Sportsman's Club, with a maximum of 0.6 mR/h recorded just beyond and falling to background 0.8 miles past the Sportsman's Club.	RaLa Shot	2	all
7/11/1957	On July 11, 1957 a leak was discovered in the buried acid waste tank outside Building #35 DP West. The contaminated ground was dug up and put into metal containers to be disposed of in the contamination dump.	Liquid Release	721	49
7/23/1957	RaLa shot # 224 took place at 1306 hours. The shot involved 1520 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 8 mph. The maximum radiation measured at distance was 0.6 mR/h at 1.5 miles; 1.0 mR/h at 2.2 miles; 0.08 mR/h at 4 miles. The team began a clockwise survey from Administration Building (SM-43) at 1335; background activity was 0.05 mR/h. Fallout was encountered 1.2 miles east past the Sportsman's Club, with a maximum of 0.6 mR/h recorded 1.4 miles past the Sportsman's Club. The same reading was recorded 2.0 miles past the Sportsman's Club. A reading of 1.0 mR/h was recorded 1.6 miles west up Guaje Canyon; 0.08 mR/h was recorded at the Puye pumice mine, although the same reading was recorded at the Administration Building, which does not seem reasonable. Contamination on the detector or the vehicle is suspected.	RaLa Shot	2	all
8/15/1957	On August 15, 1957 an explosion occurred in a glove box chain in Room 500. 18 rubber gloves were torn and three safety windows were cracked. Five men were contaminated, no skin contamination was detected after showering.	Explosion	4056	8
8/16/1957	On August 16, 1957 an explosion occurred in a glovebox chain in Room 500. Five men were contaminated with Pu.	Explosion	3490	53
8/30/1957	On August 30, 1957 large quantities of plutonium contamination were dispersed over the floor, hood and sink in three labs in J-11, contamination was also detected in the J-2 Building hallway.	Air Release	2413	4
9/27/1957	On September 27, 1957 rags contaminated with sodium and uranium caught fire in Room 133 at Ten Site. Fire was quickly extinguished with CO2.	Fire	2414	3
9/27/1957	RaLa shot # 225 took place at 1607 hours. The shot involved 1960 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.8 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1707; background activity was 0.05 mR/h. Fallout was encountered 1.4 miles east past the Sportsman's Club, with a maximum of 0.8 mR/h recorded 1.5 miles past the Sportsman's Club.	RaLa Shot	2	all
10/10/1957	RaLa shot # 226 took place at 1726 hours. The shot involved 1153 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 7 mph. The maximum radiation measured at distance (mR/h) was 0.3 mR/h at 2.2 miles. The team began a clockwise survey and reached the Sportsman's Club at 1814; background activity was 0.03 mR/h. Fallout was encountered 0.2 miles past the Rendija/Guaje junction, with a maximum of 0.3 mR/h recorded 0.4 miles down canyon. Activity continued above background until past the Guaje pumice mine. During the rest of the survey, only background activity was recorded.	RaLa Shot	2	all
11/12/1957	On November 12, 1957, a vial containing 14,000 c/m of plutonium was dropped at the stairs leading from the first floor of HRL Building.	User Error	2489	3
1/30/1958	RaLa shot # 227 took place at 1302 hours. The shot involved 1340 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. The wind speed was 13 mph. The maximum radiation measured at distance was 0.16 mR/h at 3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1343; background activity was 0.02 mR/h. Fallout was encountered at Well #1 and continued for 1.8 miles, with a maximum of 0.16 mR/h recorded 1.3 miles west up canyon from State Road 4.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
2/19/1958	RaLa shot # 228 took place at 1545 hours. The shot involved 1850 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 5 mph. The maximum radiation measured at distance was 5 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1625; background activity was 0.02 mR/h. Fallout was encountered at the Sportsman's Club, with a maximum of 5 mR/h recorded one mile east past the Sportsman's Club. Above background readings continued to Booster #2 at the junction of Rendija and Guaje canyons.	RaLa Shot	2	all
3/7/1958	RaLa shot # 229 took place at 1655 hours. The shot involved 1800 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The maximum radiation measured at distance was 1.0 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1743; background activity was 0.03 mR/h. Fallout was encountered 1.9 miles east past the Sportsman's Club, with a maximum of 1.0 mR/h recorded 2.1 miles past the Sportsman's Club. Above-background activity was recorded to the junction of Rendija/ Guaje canyons.	RaLa Shot	2	all
4/3/1958	RaLa shot # 230 took place at 1505 hours. The shot involved 1100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NW, NE. The wind speed was 5 mph. No radiation was detected. The team began a clockwise survey from the Administration Building (SM-43) at 1535 for a clockwise perimeter survey. All readings showed background activity.	RaLa Shot	2	all
5/1/1958	RaLa shot # 231 took place at 1430 hours. The shot involved 1134 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNW. The wind speed was 10 mph.	RaLa Shot	2	all
6/3/1958	RaLa shot # 232 took place at 1450 hours. The shot involved 1316 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 12 mph. The maximum radiation measured at distance was 0.18 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1535; background activity was 0.05 mR/h. Fallout was encountered at the Rendija/Guaje junction, with a maximum of 0.18 mR/h recorded 0.7 miles down canyon. The remainder of the survey recorded background activity.	RaLa Shot	2	all
7/25/1958	Large quantities of tritium were released in the filling chamber of Room 9 of the HP-86 facility at TA-33 on July 25, 1958. It was estimated that 13,000 curies were lost. Building 86 was evacuated and road blocks were set up.	Air Release	2422, 4057	4, 20
10/28/1958	A fire was detected on October 28, 1958 in pit #6 of the contaminated dump.	Fire	4057	27
11/6/1958	On November 6, 1958 K Division members were removing a plutonium pilot plant from the air filter building, contamination was spread to the floor, wheels of the fork lift, and the dirt east of the building.	Contam. Event	2510	3
12/8/1958	RaLa shot # 233 took place at 1545 hours. The shot involved 1305 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 1.4 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1600; background activity was 0.03 mR/h. Fallout was encountered, twice background, in the “new housing area” (Barranca Mesa), and 1.0 mR/h was recorded at the end of Tank Mesa (Barranca Mesa, overlooking the firing site). Back on the clockwise perimeter survey route, fallout was encountered 1.2 miles east past the Sportsman's Club, with a maximum of 1.4 mR/h recorded at the Guaje Canyon gate. The remainder of the survey route showed background activity.	RaLa Shot	2	all
12/30/1958	On December 30, 1958 there was a criticality incident involving 3.27 kg Pu $Pu0_2(N0_3)_2$ in ~168 liters of water. The cylinder contained dissolved Pu, when the agitator was stared it created critical geometry. One death resulted from the accident. 1.5×10^{17} total fissions were involved.	Criticality	6206	all
2/20/1959	RaLa shot # 234 took place at 1335 hours. The shot involved 1250 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.18 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1405; background activity was 0.04 mR/h. Fallout was encountered 0.5 miles past the Sportsman's Club and continued for 2 miles, with a maximum of 0.18 mR/h recorded at Booster #2, which is 1.2 miles east of the Sportsman's Club.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/13/1959	RaLa shot # 235 took place at 1405 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 20 to 100 lbs. No radiation was detected. The team left the Administration Building (SM-43) at 1426; background activity was 0.05 mR/h. The team completed the counterclockwise survey; all readings showed background activity.	RaLa Shot	2	all
3/17/1959	On March 17, 308 curies of tritium were released to the outside when a valve on a Van de Graff was left open.	Air Release	2739	3
4/1/1959	During processing of irradiated U-235 at TA-48 uranium oxide was blown out of the hood when a sample can was opened.	Explosion	2514	4
4/2/1959	RaLa shot # 236 took place at 1635 hours. The shot involved 980 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the ESE. The maximum radiation measured at distance was 0.6 mR/h at 3 miles. The team left the Administration Building (SM-43) at 1750 to conduct a clockwise survey; background activity was 0.03 to 0.04 mR/h. Fallout was encountered at the intersection. The fallout continued west along State Road 4 for 3 miles, with a maximum of 0.6 mR/h recorded 1.5 miles west of the Guaje/State Road 4 intersection (12 mR/h was recorded at an isolated spot). The remainder of the survey showed background activity. The cloud was observed to go over the north Bayo Canyon wall.	RaLa Shot	2	all
4/14/1959	RaLa shot # 237 took place at 1250 hours. The shot involved 1140 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.4 mR/h at 1.7 miles. The team left the Administration Building (SM-43) at 1401; background activity was 0.03 to 0.04 mR/h. Fallout was encountered 1.2 miles past the Sportsman's Club, and readings remained elevated to the White Rock junction on State Road 4. A maximum of 0.4 mR/h was recorded 2 miles past the Sportsman's Club.	RaLa Shot	2	all
5/1/1959	During the operation of LAMPRE II radioactive gas was released through the exhaust system, causing an increase in background levels around the town site. High background levels were detected in the water boiler reactor room due to a disconnected exhaust pump in the valve house, the incident increased background levels around the town site.	Air Release	2515	4
5/15/1959	RaLa shot # 238 took place at 1547 hours. The shot involved 1040 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ESE. The team left the Administration Building (SM-43) at 1640; background activity was 0.03 to 0.05 mR/h. A clockwise survey was conducted; only background activity was recorded until fallout was encountered on the Main Hill Road 0.8 miles east of the main gate for about 0.6 miles. A maximum of 1.5 mR/h was recorded beyond the East Gate Laboratory at the entrance to the Camp Hamilton Trail. Because the cloud was reported to go down canyon (east-southeast), the readings are not believed to be related to the Bayo Canyon activity. During this period, a large 120-curie cobalt-60 source located about 400 feet directly north of the Main Hill Road at the East Gate Laboratory (TA-19) was in intermittent use and is believed to explain these readings (see also shots #240 and #242).	RaLa Shot	2	all
6/4/1959	RaLa shot # 239 took place at 1527 hours. The shot involved 995 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The maximum radiation measured at distance was 0.4 mR/h at 2.7 miles. The team left the Administration Building (SM-43) at 1630; background activity was 0.04 mR/h. During the clockwise survey, above-background activity was encountered at Booster #1, 3 miles east of the Sportsman's Club. It continued for 1.4 miles, with a maximum reading of 0.4 mR/h recorded 3.8 miles past the Sportsman's Club.	RaLa Shot	2	all
6/26/1959	RaLa shot # 240 took place at 1400 hours. The shot involved 954 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.12 mR/h at 2.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1419; background activity was 0.02 mR/h. Fallout was encountered at the Guaje pumice mine and continued for 1.6 miles, with a maximum of 0.12 mR/h recorded 0.8 miles past the mine. Fallout was encountered again on the Main Hill Road 1.3 miles east of the main gate, with a maximum of 1.3 mR/h recorded 0.5 miles east of the gate. Because the cloud was reported to have gone over the north wall of Bayo Canyon, this reading is again attributed to the gamma source at the East Gate Laboratory (see shots #238 and #242).	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/15/1959	On July 15, 1959 a fire broke out in a plutonium contaminated CWS exhaust filter in Room 501 DP West. Highly contaminated ash was dispersed throughout the room. The clothes of 12 firemen were held for decontamination. This occurred during welding of a new section of exhaust duct on the discharge side of the filter unit.	Fire	19, 2425	55, 5; 6
7/17/1959	Tritium gas was released from a storage tank reservoir in Building 86 at TA-33 on July 17, 1959. Road blocks were established and 69 people were evacuated from the area. No appreciable radiation was measured outside the fence of Building 86.	Air Release	2425	5, 6
8/14/1959	On August 14, 1959 a tritium leak occurred at P-9 Van de Graff area when an "o" ring allowed tritium to be released.	Air Release	2426	3
10/7/1959	RaLa shot # 241 took place at 1438 hours. The shot involved 893 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The wind speed was 12 mph. The maximum radiation measured at distance was 0.12 mR/h at 3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1603; background activity was 0.05 mR/h. Questionable activity (only 0.01 mR/h over background) was encountered at Booster #1 for 4.2 miles, with a maximum of 0.12 mR/h recorded 1.5 miles past the Guaje pumice mine. During the remainder of the survey, only background activity was recorded.	RaLa Shot	2	all
10/14/1959	Explosion occurred while disposing of scrap and waste explosives	Explosion	NA	58
12/3/1959	A fire occurred on December 3, 1959 in the drybox exhaust ductwork in Room 313 of DP West during the burning of U-235 contaminated rags. The exhaust stack discharged black smoke toward the west for approximately 15 minutes. A neoprene duct connection had burned out releasing contamination to the roof. Damage was limited to the ductwork. Alpha contamination was detected downwind of Room 313.	Fire	19, 2494, 4058	57, 3, 1
12/16/1959	On December 16, 1959 a filter in the vent line of the neutralization tank at the waste treatment operation at DP West failed allowing plutonium and americium to run down the roof and contaminate the ground.	Liquid Release	2494	3
1/15/1960	On January 15, 1960 in Room 308 of DP West a bottle containing plutonium solution had shattered. Contamination was tracked into the main hallway and into Room 206 and 363. Airborne contamination spread into 313, 322 and 326. the air supply room on the south side of Building 3 was monitored and found to be highly contaminated.	Liquid Release	3971	18
2/13/1960	Two different explosions occurred in the rag incinerator in Room 313 of DP West on January 28, 1960 the other on February 3, 1960. The February 3, 1960 explosion in Room 313 of DP West occurred during the burning of U-235 contaminated rags. The area was monitored and no surface contamination was detected.	Explosion	2496, 3971	3, 14
3/8/1960	RaLa shot # 242 took place at 1648 hours. The shot involved 908 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the S. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1717; background activity was 0.03 mR/h. Since the cloud was observed to travel down canyon, the activity that was encountered 1.7 miles east of the airstrip and continued for about 0.5 miles, with a maximum of 1.5 mR/h recorded 1.9 miles past the airstrip, is believed to be due to the gamma source at the East Gate Laboratory (see shots #238 and #240 above). The remaining readings, beginning about 1.5 miles west of Roy's Service Station (Totavi) and continuing for about 1.3 miles, are attributable to this shot. A maximum reading of 0.4 mR/h was recorded 0.9 miles west of Roy's Service Station.	RaLa Shot	2	all
4/13/1960	On April 13, 1960 in Building HP 21 there was widespread plutonium contamination when 100mg of plutonium was released during an experiment.	Contam. Event	2498	4

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
5/4/1960	RaLa shot # 243 took place at 1618 hours. The shot involved 957 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The maximum radiation measured at distance was 1.3 mR/h at 2.1 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1645; background activity was 0.02 to 0.03 mR/h. Fallout was encountered 0.7 miles west of Well #1 and continued for 2.5 miles, with a maximum of 1.3 mR/h recorded 1.3 miles past Well #1. At Well #1, a particle was collected reading 1100 mR/h at "contact" with a Cutie Pie (an ionization chamber instrument). Background readings during this survey seemed to fluctuate. The environmental group reported results of two film badge dosimeters planted at the airstrip, about 1 mile southwest of the firing site, for a period beginning 22 days before and ending 30 days after this shot. They reported the readings averaged 200 mR/mr over this period and attributed the dose to a possible particle from the main cloud, although the main cloud went in the opposite direction.	RaLa Shot	2	all
6/17/1960	On June 17, 1960 there was a criticality incident involving ~48 kg U-235. Uranium cylinders in thick graphite (9-in.) reflected before complete assembly, resulting in trivial damage. 6×10^{16} total fissions were involved.	Criticality	6206	all
9/1/1960	RaLa shot # 244 took place at 1300 hours. The shot involved 1120 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N and NW. The maximum radiation measured at distance was 0.3 mR/h at 1.2 miles; 0.3 mR/h at 2 miles. The team began a clockwise perimeter survey from the Administration Building (SM-43) at 1325; background activity was 0.05 mR/h. Fallout was encountered 0.8 miles east past the Sportsman's Club and continued for 0.8 miles, with a maximum of 0.3 mR/h recorded 1.1 miles past the Sportsman's Club; 2.1 miles west up Guaje Canyon the maximum was 0.3 mR/h. A resurvey the next morning found a "speck" reading of 1.1 mR/h at "contact" on Guaje Road, where the maximum reading was found the day before.	RaLa Shot	2	all
9/16/1960	On September 16, 1960 or September 14, 1960, 15-30 gallons of americium raffinate were spilled from a tank at Building 35 DP West. A trailer and the ground surrounding the trailer were contaminated and cleaned.	Liquid Release	2429, 2971	5, 8
9/21/1960	On September 21, 1960 a small explosion occurred in the Room 201 incinerator. The room was decontaminated the following day.	Explosion	3971	7
10/11/1960	RaLa shot # 245 took place at 1408 hours. The shot involved 1100 Ci of RaLa with an explosive charge of 20 to 100 lbs. The team started a survey on Barranca Mesa, completing a clockwise route. All readings were recorded as "00."	RaLa Shot	2	all
11/22/1960	RaLa shot # 246 took place at 1214 hours. The shot involved 1475 Ci of RaLa with an explosive charge of 101 to 200 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
2/17/1961	RaLa shot # 247 took place at 1650 hours. The shot involved 7090 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
3/24/1961	On March 24, 1961 a contamination incident occurred during the disassembly of a drybox on a milling machine at DP Site. The turntable was taken to the contaminated truck for wrapping. The turntable was opened to facilitate further wrapping and in doing so some plutonium dust was released. A strong gust of wind blew spread contamination to the truck, the adjacent building, and surrounding ground. A large airborne count of alpha contamination was measured in Building 54 during the incident.	Air Release	19, 2520, 4059	85, 4, 15
5/19/1961	RaLa shot # 248 took place at 1314 hours. The shot involved 3902 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
6/20/1961	RaLa shot # 249 took place at 2019 hours. The shot involved 5300 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
8/7/1961	On August 7, 1961 a container with a uranium fuel element leaked. Contamination products were detected in the parking lot and around the building. No decontamination was done.	Air Release	2524	4

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
9/28/1961	On September 28, 1961 a spill occurred in the liquid waste sampling room located in the northeast of Building 2, DP West. The drain line stopped up and contaminated liquid flowed down the storm drain. Workmen from Room 326 had walked through the area. Their homes and personal shoes were monitored and no contamination was detected.	Liquid Release	4059	10
10/11/1961	RaLa shot # 250 took place at 1302 hours. The shot involved 3870 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
11/17/1961	RaLa shot # 251 took place at 1430 hours. The shot involved 4150 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
11/28/1961	On November 28, 1961 a spill was discovered on the ground north of the pump house of Building 700. The spill was monitored and contamination was found.	Liquid Release	4059	4
12/10/1961	The GNOME nuclear test, the first test in the Plowshare Program, was conducted near near Carlsbad, NM. The device was placed at a depth of 1,185 ft in a shaft drilled in salt. The objectives of the 3 kiloton test were isotope recovery, neutron physics experimentation, examination of heat recovery, seismic measurements, and explosive development. The shot also had a Vela Uniform Program objective to determine how the seismic signals and effects of a 3-kiloton device detonated underground in salt beds differed from the outputs of detonations of different yields in other geologic formations such as tuff and granite and from signals caused by earthquakes. [Ref: http://www.nv.doe.gov/library/films/fulltext/0800034.htm and https://www.osti.gov/opennet/reports/plowshar.pdf]			
1/30/1962	RaLa shot # 252 took place at 1908 hours. The shot involved 6077 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
2/2/1962	RaLa shot # 253 took place at 1341 hours. The shot involved 1590 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
3/6/1962	RaLa shot # 254 took place at 1330 hours. The shot involved 5940 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
3/9/1962	On March 9, 1962 .8 g of tritium were released into the atmosphere during an experiment at TA-41.	Air Release	4060	8
12/11/1962	On December 11, 1962 there was a criticality incident involving U-235 foils in graphite. The assembly went critical when it was ran due to inadequate communication between work crews. 3×10^{16} total fissions were involved.	Criticality	6206	all
2/27/1963	On February 27, 1963 approximately 48 millicuries if radioactive iodine was release out the stack of Cell 9, Wing 9, CMR Building.	Air Release	4061	18
3/4/1963	On March 4, 1963 radioactive I-131 was released from Stack #2.	Air Release	2072	150
4/8/1963	On April 8, 1963 there was a uranium spill at TA-46.	Contam. Event	2536	2
6/1/1963	During maintenance, a spark from a welding operation started a fire in the filter of a plutonium drybox at DP West, releasing plutonium into air.	Fire	2538	3
6/6/1963	On June 6, 1963 a fire occurred in a drybox air intake filter in Room 213 of DP West. No contamination was detected in the vicinity of the drybox.	Fire	4061	16
7/31/1963	On July 31, 1963 an employee spilled some contaminated material from a U-235 rag incinerator onto the hood and floor of Room 313 DP West.	Contam. Event	4061	9
11/15/1963	On November 15, 1963 P-9 accidentally released 2 cc of tritium gas.	Air Release	2502	4
11/26/1963	On November 26, 1963 a worker was found to have contamination on his clothing. His personal car and home were monitored and no contamination was found.	User Error	4061	2
1/10/1964	On January 10, 1964 in SM-66 depleted uranium residue ignited in a drum. The material was allowed to burn out.	Fire	2812	3

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
2/11/1964	Omega Site was contaminated when a sample reading 4.5 R/hr at 1 m was removed from OWR vertical port and dragged down the road (because of its weight) to the storage area.	Contam. Event	2812	3
4/12/1964	An explosion occurred in Room 313 rag incinerator drybox following ignition of a batch of U-235 contaminated rags on April 12, 1964. The fire spread from the drybox into the adjoining hood and ignited another batch of rags. The fire was quickly extinguished.	Explosion	11	297
4/22/1964	An explosion occurred in an incinerator drybox following a fire in Room 313 DP West from U -235 contaminated rags on April 22, 1964. The fire spread from the drybox to the adjoining hood.	Fire, Explosion	2505, 4062	4, 5
7/2/1964	Explosion attributed to accumulation of unburned gas in area of stagnant air movement in furnace upper passageways, damaged boiler furnace	Explosion	NA	78
7/31/1964	On July 31, 1964 high levels of contamination were detected in a hood after an accidental plutonium release. The hood was decontaminated, but the stack was likely contaminated.	Air Release	2507	4
10/3/1964	On October 3, 1965 there was a tritium release at P-9. Approximately 100 curies of tritium was released.	Air Release	4063	3
11/11/1964	On November 11, 1964 there was a fire in pit 3 of area G (Mesita del Buey). The cause of the fire is unknown.	Fire	4062	5
2/16/1965	On February 16, 1965 approximately two liters of tritium gas were released up the stack during an experiment.	Air Release	4063	12
2/17/1965	An estimated 10 Ci of tritium were released on February 17, 1965 from the hood in Room 4130 of CMF-4.	Air Release	2072, 4063	261, 12
4/14/1965	On April 14, 1965 in Building 35 sludge filtering room, approximately 25 gallons of contaminated sludge spilled when a pipefitter disconnected a flange in the sludge filtering tank. The area was quickly decontaminated.	Liquid Release	4063	12
5/28/1965	On May 28, 1965 at White Sands Missile Range there was a criticality incident involving 96 kg enriched U-Mo alloy, due to incorrect operation. The assembly bolts broke, and there was minor damage to coating. 1.5×10^{17} total fissions were involved.	Criticality	6206	all
6/1/1965	At DP East the gas purge line to a recovery furnace became plugged. The operator in charge removed a rubber hose connected to the unit, and uranium-containing dust was blown out into his face and onto his clothing.	User Error	NA	2
12/1/1965	During the removal of a rod coated with Am-241 from an experimental apparatus, personal clothing of the operator was contaminated.	User Error	NA	4
4/15/1966	On April 15 and 16, 1966 there was a "large spill" of tritium at P-9 due to a diaphragm failure.	Air Release	4064	6
5/11/1966	An explosion occurred in a rag incinerator globe box in the U-235 recovery area at DP West. The explosion cracked the window of the glove box.	Explosion	NA	4-5
6/9/1966	On June 9, 1966 there was a tritium spill at P-12.	Air Release	4064	6
11/16/1966	The air cleaner at one of the enriched uranium shops developed a pin-hole leak, which resulted in high surface contamination of the surrounding area.	Air Release	NA	3
7/14/1967	A fire occurred on July 14, 1967 in Room 313 of DP West. Sparks from the incinerators escaped and ignited the pre-filter located in a well in the loading drybox floor. The flames swept up the exhaust line and ignited the HEPA filter in the drybox. The Building 3 roof was monitored and no contamination was detected.	Fire	4065	10
12/1/1967	An explosion occurred in the rag-incinerator drybox in Room 313 DP West on Dec. 1, 1967 during the incineration of U-238 contaminated rags.	Explosion	NA	4

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
12/10/1967	The GASBUGGY nuclear test was conducted in the San Juan Basin, 55 miles east of Farmington, New Mexico. The device was placed at a depth of 4,240 ft in a shaft drilled in a gas-bearing sandstone formation. The objective of the test was to investigate the feasibility of using nuclear explosives to stimulate a low-permeability gas field. GNOME was the first Plowshare joint government-industry nuclear experiment to test an industrial application. [Ref: https://www.osti.gov/opennet/reports/plowshar.pdf]			
1/1/1968	In early January 1968 members of group J-11 were working with Pb-210 at TA-48. During routine monitoring one employee's shoes were found to be contaminated. The homes of several employees were monitored and one was found to be contaminated. The home was decontaminated.	Contam. Event	4066	12
2/1/1968	Four days after a Pb-210 spill in February 1968, Pb-210 contamination was detected in the home of an employee, the area was decontaminated.	Contam. Event	817	13-14
2/7/1968	On February 7, 1968 approximately 100 cc of tritium gas was released in Room 4136 Wing 4 of CMR Building.	Air Release	4066	36
2/8/1968	100 cc of tritium gas may have been released from the exhaust system to the environment on February 8, 1968.	Air Release	1180	8
3/1/1968	An employee broke a charcoal trap which contained approximately 100 cc of tritium, which was released into the exhaust system In March of 1968.	Air Release	817	13
4/26/1968	At TA-48 some Pb-210 was spilled on the floor and tracked out of the laboratory. The spill was not detected until 4 days later when Pb-210 was detected during routine surveys. One home had spots reading up to 1500 cpm of alpha radiation on the rug. The rug in the home was removed.	Contam. Event	NA	5
6/4/1968	The sidewalk, driveway, and rug in the home of an employee were contaminated with Pb 210 sometime around June 14, 1968.	Contam. Event	4066	10
9/17/1968	There was an air duct fire in Building 3 between the exhaust blower near Room 313 and the main stack at DP West on September 17, 1968. The fire was due to a welding operation. No contamination was detected on the roof or duct work.	Fire	817, 4066	2-3, 2
1/2/1969	On January 2, 1969 a contamination accident occurred in Room 606 DP West resulting in the release of plutonium dust.	Contam. Event	NA	6-7
1/15/1969	A glovebox explosion occurred in the uranium recovery operation at DP West, during the incineration of U-235 metal turnings.	Explosion	NA	3
1/15/1969	During the removal of Pu-239 contaminated waste materials from a glovebox line at DP West, the transfer bag ruptured.	Explosion	NA	3
2/27/1969	On February 27, 1969 a fire occurred in the #2 glovebox line in Room 500 DP West, resulting in the release of plutonium dust contamination.	Fire	NA	6-7
3/3/1969	On March 3, 1969 a fire occurred in the leaching hood in Room 313 DP West, during leaching of U-235 contaminated filter frames.	Fire	NA	6-7
3/25/1969	On March 25, 1969 an explosion occurred in the glovebox of Room 313 DP West. The explosion blew out U-235 dust contamination into the Room.	Explosion	NA	6-7
6/26/1969	On June 26, 1969 an explosion occurred in the rag incinerator box in Room 313 DP West during the burning of U-235 turnings. The explosion scattered contamination through out the room.	Explosion	NA	5
8/21/1969	On August 21, 1969 approximately 5.73 liters of tritium gas was released into the atmosphere at TA-33.	Air Release	4067	4
10/1/1969	"High levels" of airborne plutonium were detected in the room when a CMF-5 employee dropped a plutonium containing sample.	User Error	4182	3,4
10/14/1969	On October 14, 1969 a contamination incident occurred in Room 308 DP West, resulting in the release of plutonium dust contamination from a trash bag. The incident occurred during the transfer of trash from a glove box in a plastic bag. The bag ruptured resulting in the contamination of the floor. A CMF-5 staff member accidentally dropped a container with plutonium inside. The lid of the container cam off resulting in a high level of airborne Pu contamination.	Air Release	4182, NA	3, 4-5

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
1/16/1970	On January 16, 1970 ZIA craftsmen pumped a caustic solution into the negative water pressure circulating tank in the Building 150 stairwell DP West. Highly contaminated foam escaped through a vent pipe, contaminating the tank, grill, west wall, and stairwell.	Liquid Release	NA	7
4/3/1970	On April 3, 1970 a furnace containing uranium exploded releasing dust in SM-35 Room 104.	Explosion	4261	1
6/10/1970	On June 10, 1970 a tri-state tractor trailer was found to be contaminated with Co60. The trailer was decontaminated, but the source of the contamination is a mystery.	Contam. Event	NA	4
7/1/1970	A minor fire occurred in the hood of a rag incinerator in Building 3 of TA-21 which was associated with recovery of U-235 oxide.	Fire	NA	4
7/1/1970	On May 1, 1970 a ruptured exhaust filter allowed for an increase in air activity. The filter was replaced and no background contamination was found outside of SM-35.	Air Release	NA	4
9/17/1970	On September 17, 1970 a fire started in a dust collection jar of a vacuum in Room 104 of TA-3-35. The fire started as a result of a spark during the cutting of U-235 fuel elements.	Fire	NA	9
10/7/1970	On October 7, 1970 a capillary tube containing $^{238}PuO_2$ broke in an open-faced hood in Room 605a of Building 150 of DP West. The hood exhausted directly to the roof without filtration. The room under the stack was contaminated in an area of approximately 100 square feet. Areas of contamination were found on the roof of the office trailer parked northwest of Building 150. No other contamination was found. The areas were decontaminated.	Air Release	4068	6
10/7/1970	A sample of radioactive tritiated salt was lost at Los Alamost Scientific Laboratory. The sample was reported missing 9-29-70 after routine inventory. An exhaustive search failed to turn up the missing sample.	User Error	NA	120
3/29/1971	On March 29, 1971 during the emptying of a dumpster of radioactive waste at TA-54 (pit 6, area G) Pu-238 became airborne and contaminated the truck carrying the dumpster. The decontamination did not escape the disposal pit.	Air Release	3972, 4705, NA	106, 4, 5
7/31/1971	On July 31, 1971 employees were working with a capsule (disassembly of a transit heat source containing 26,092 Ci of Pu-238) in Room 9130, Wing 9, CMR Building. Contamination was released into the room and the workers were contaminated. 55 microcuries escaped the building over a period of 16.5 hours.	Air Release, Contam. Event	3972, 5442	5, 1
10/7/1971	On October 7, 1971 a release of Pu-238 oxide occurred in 605 DP West contaminating 200 sq ft of the building, the roof and the surrounding ground.	Contam. Event	NA	6
10/15/1971	There was a fire in exhaust filter SM-102 on October 15, 1971.	Fire	1417	3
11/2/1971	On November 2, 1971 an explosion in test cell furnace blew uranium contamination onto floor.	Explosion	1417	3
12/17/1971	On December 17, 1971 high Pu-238 air counts were detected due to contamination from an exploding bottle.	Explosion	1417	3
8/1/1973	XO-2 cooling loop leaks at TA-53 allowed 1.5 Ci of tritium to be transferred along with 25,000 L of waste water from the waste tanks in the experimental area to the sewage lagoons at TA-53 between July 1, 1978 and September 30, 1978.	Air Release	NA	32
7/9/1974	On July 9, 1974 it was discovered that a pipe conveying radioactive wastes to TA-50 was leaking north of Pajarito road east of TA-3-184. The section of pipe was repaired.	Liquid Release	515	6
8/14/1975	On Aug. 14 approximately 10 gallons of reactor water went down the drain to the dry creek bed.	Liquid Release	392a	16
8/27/1975	On Aug. 27, 1975 approximately 960 gallons of regenerate material spilled out of a sludge holding tank contaminating Room 60A, TA-50. Approximately 500-700 gallons was lost outside. The solution contained Cs, Pu, St, Am. The spill area was roped off, covered with wet sand to minimize airborne contamination, and cleaned.	Liquid Release	392a	15

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
1/1/1976	In 1976 approximately 3271 Ci of tritium was release into the environment (this does not include 22,000 Ci released from TA-3-34 on July 15, 1976).	Air Release	NA	13
7/15/1976	On July 15, 1976 there was a tritium release from TA-3-34 of 22,000 Ci.	Air Release	NA	15
1/1/1977	In 1977 approximately 6417 Ci of tritium was released into the environment (this does not include 30,800 Ci released from TA-33-36 on October 6, 1977).	Air Release	NA	13
10/6/1977	On October 6, 1977, approximately 33,217 Ci of tritium gas was released from Room 9 at TA-33-86 due to a loose high pressure fitting. Averaged over 24 hours the stack concentration was 0.104 µCi/ml.	Air Release	1232, Na, NA	5, 18, 15
11/11/1977	On November 11, 1977, at TA-54 Burial Pit seven bales of suspect low-level radioactive contaminated combustible waste auto-ignited. Apparent cause was a bottle, or bottles of acid improperly disposed of in the combustible waste.	Fire	NA	22
8/22/1978	On August 22, 1978 SM-102 a drum of depleted U-238 chips ignited while being moved to the outside.	Fire	NA	18
10/30/1978	It was discovered on October 30, 1978 that a large amount of tritium was released when a glass ballast valve was left open.	Air Release	3462	3
12/1/1978	An LASL employee contaminated the sleeve of his shirt, which was not detected until the employee returned to work following day. No contamination was detected at his home or in his automobile.	User Error	NA	10
5/4/1979	A stainless steel pot containing uranium tritide was overheated in a laboratory at the Cryogenics Building (TA-3-34) and ruptured on May 4, 1979. Tritiated water escaped into the laboratory because of inadequate air flow in the hood. ~3,000 Ci of tritium was released to the atmosphere.	Air Release, Liquid Release	3462, 4484, NA	102, 1-2, 18
5/7/1979	Tritium exposure incident at SM-34 on May 4, 1979.	Contam. Event	NA	4
5/18/1979	On May 18, 1979 during the transfer of 1500 gallons of contaminated water from the north holding tank to LAMPF Site sewage lagoons. The area A parking lot and area A shop floor were flooded, procedures to prevent the spread of contamination were used and the areas were quickly decontaminated.	Liquid Release	4154	91
5/25/1979	On May 25, 1979 approximately 3000 Ci of tritium were released from SM-34.	Air Release	4154	94
8/22/1979	On August 22, 1979 approximately 200 grams of UF6 was released at Building 23 TA-18 Pajarito Site. Approximately 0.0038 grams was released into the environment. The majority of the ~200 grams (~180 grams) was caught in the HEPA filter.	Air Release	4154	20
9/17/1979	A dempster dumpster fire occurred at TA-33-86 on September 17, 1979. The only radioactive isotope believed to be present at the time of the fire was tritium.	Fire	4154	6
12/12/1979	On December 12, 1979 150 to 200 gallons of slightly radioactive primary reactor system water was released at TA-2 inside Building 44. Approximately 50 gallons drained to a nearby creek via a floor drain in Building 44.	Liquid Release	4154	1
11/1/1980	In November 1980 there was a release of 16 curies of tritium gas and a total of 10 minor radiation releases of plutonium in labs reported internally.	Air Release	933	19
2/1/1981	In February 1981 a total of 11 minor radiation accidents were reported internally.	Contam. Event	936	17
3/19/1981	On March 19, 1981 liquid from an industrial waste line serving TA-48 was inadvertently pumped into Mortandad canyon.	Liquid Release	NA	128-129
3/24/1981	On March 24, 1981 several curies of gaseous tritium were released from the Van de Graaff Building at TA-3.	Air Release	NA	128-129
10/14/1981	On October 14, 1981 ten samples contaminated with PuO_2 were opened in a laboratory where Pu is not normally handled. Contamination was spread into several laboratories, a small shop, the analyst and several other workers before it was detected. One vehicle and two homes were contaminated with a small amount of material. All employees and contaminated areas were readily decontaminated. This occurred at TA-3, SM-29.	Contam. Event	2057, NA	8, 35

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
11/1/1981	In November 1981 ten minor radiation releases were documented and investigated internally at LANL.	Contam. Event	935	20
3/19/1982	On March 19, 1982 a section of the industrial waste line carrying fission products from hot cells serving TA-48 had been found leaking. A limited area of soil was contaminated within Laboratory boundaries. The affected soil from the areas along both sides of the road behind TA-48 were removed (down to bedrock) up to the edge of Mortandad Canyon, and replaced with clean soil.	Liquid Release	4412	1
8/10/1982	On August 10, 1982 a furnace at TA-55 ignited and over pressurized a glovebox. Two glovebox windows ruptured releasing alpha contamination into the room and adjacent corridor.	Air Release	NA	6
11/2/1982	On November 2, 1982 approximately 50-100 liters of waste liquid escaped from a tank vent at TA-21-257 contaminating the building roof, walls, and surrounding area with low levels of plutonium, americurium, and uranium.	Liquid Release	NA	6
1/10/1983	An accidental release of chromium oxychloride occurred at the Van de Graaff facility on January 10, 1983. The accident occurred when an employee removed a valve from one end of a pipe which allowed for the liquid stored in the pipe to spill on the floor.	Liquid Release	NA	4
6/1/1983	On June 1, 1983 high airborne plutonium levels were detected in Room 429 at TA-55 Building PF-4. The high levels were caused by a leak in the dry vacuum line to a glovebox.	Air Release	NA	1
6/1/1983	Radiation material was discovered in the salvage yard and reported during the report period.	Contam. Event	NA	4
8/25/1983	On August 25, 1983 a puff release of 104 Ci of tritium occurred at TA-33. This was followed by a slow release of an additional 45 Ci in the subsequent 24 hour period.	Air Release	NA	4
11/28/1983	On November 28, 1983 a fire occurred in the well house at Pajarito water supply well no. 2. Two large PCB capacitors were involved in the fire emitting PCB when the heat caused them to rupture releasing their contents. Air and ash samples confirmed significant PCB contamination inside the building.	Fire	NA	3-4
12/6/1983	On December 6, 1983 two plutonium containing shipping containers were inadvertently opened, contaminating the clothing and skin of eight workers.	Contam. Event	NA	3-4
2/17/1984	Fire at TA-50 Building 1 in a ventilation exhaust plenum on February 17, 1984, filter bags were ignited.	Fire	NA	6
4/10/1984	Hydrogen fluoride release on April 10, 1984 from Room 5096 at TA-3-29 through a hole in an exhaust flex hose of the gas centrifuge.	Air Release	NA	4-5
7/1/1984	There was a fire at the lithium hydride shop TA-3, SM-39 on June 6, 1984. Lithium hydride dust ignited in a section of exhaust duct.	Fire	NA	4-5
7/26/1984	Equipment failure to contain plutonium solution resulting in significant area contamination and high nose swipes for three employees on July 26, 1984 at TA-55-4-401.	Equipment Malfunction	NA	2-3
10/19/1984	Inadequate procedures when handling packaged Pu-238 resulted in widespread area contamination and contamination of personal clothing of two employees on October 19, 1984 at TA-54.	Contam. Event	NA	2-3
1/11/1985	On January 1, 1985 a failure to comply with established procedures resulted in a release of radioactive materials along a public roadway (report no. LAMPF-85-1).	Contam. Event	NA	6
6/1/1985	60 gallons of tri-methyl benzene were spilled in the neutrino area at the L.A. Meson Physics Facility, no serious injuries resulted form this accident.	Liquid Release	NA	6
6/12/1985	On June 12, 1985 the improper transfer of radioactive material resulted in an employee's home being contaminated (Report no. AHP-85-8).	Contam. Event	NA	6
7/1/1985	On July 1, 1985 activated cooling water was discharged outside facility (Report no. LAMPF-85-5).	Liquid Release	NA	6

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
9/12/1985	On September 12, 1985 there was a fire in a glove box at TA-55-4-429 which resulted in high airborne activity and area contamination (Report no. CHEM-HP-85-20).	Fire	NA	6
2/2/1986	On February 2, 1986 there was an unexpected release of tritium oxide at TA-41-4-236A.	Air Release	NA	11
10/30/1986	On October 30-31, 1986 an estimated 633 Ci of tritium were released at TA-33, mostly in the form of tritiated water.	Air Release	NA	8
11/14/1986	On November 14, 1986 11.5 Ci of tritium was released from TA-33 in the form of elemental tritium.	Air Release	NA	8
11/1/1987	Low level liquid waste from TA-55 showed higher than normal levels of plutonium in Nov. and Dec. There was a pinhole leak in a stream coil in a cascade dissolver process at TA-55	Liquid Release	NA	4
2/22/1988	On Feb 22, approximately 5800 Ci of tritium were released from TA-33.	Air Release	1246	8
2/27/1990	On February 27, 1990 cooling water overflowed in the exhaust system of TA-55-4.	Liquid Release	NA	8
3/1/2000	An incident occurred in March 2000 when eight workers at TA-55 were exposed to airborne plutonium.	Air Release	NA	1
3/1/2000	An incident occurred in 1998 when a worker at TA-55 was exposed to airborne plutonium.	Air Release	NA	1
5/4/2000	On May 4, 2000 a wild fire was ignited which ulitmately burned nearly 50,000 acres in and around Los Alamos New Mexico.	Fire	NA	1
7/27/2005	A small amount of americium-241 was found to have contaminated a package that was shipped from Los Alamos to Pennsylvania. The contamination was spread to homes in Colorado, Kansas, and New Mexico.	Contam. Event	6204	all

Chapter 17: Prioritization of Radionuclide Releases

The LAHDRA team identified the following steps for prioritizing radionuclide releases:

1) Review the history of LANL operations,
2) Identify relevant data concerning air and liquid releases,
3) Correct or adjust older data with appropriate factors based on current state-of-the-art methods,
4) Fill in data gaps with justifiable methods for estimating air and liquid releases, and
5) Prepare a prioritized list of radionuclides for both operational and episodic releases.

The goals for prioritizing historical radionuclide releases were to provide a relative ranking of releases that may have impacted public health, and to limit attention to radionuclides that did not appear to impact human health. Prioritization to date has been accomplished using a method based on determining the volume of air or water required to dilute the radionuclide in question down to the maximum allowable concentration for a release to the environment. This dilution volume is defined as the Priority Index (PI). For example, a PI of 10^6 liters means that one million liters of air (for an airborne release) would be required to dilute the amount of released material down to the maximum allowable effluent concentration. This simple method does not require defining a specific "receptor" or using an exposure pathway model. However, for certain historical releases, the LAHDRA team decided to conduct a more developed evaluation based on the screening methods of National Council on Radiation Protection and Measurements (NCRP) Report No. 123 (NCRP, 1996). These screening evaluations are described in Chapters 9 and 18.

Priority Indices were calculated based on estimated quantities released and maximum effluent concentrations documented in Title 10 of the Code of Federal regulations, Part 20 (USNRC, 2010). These values are intended to be guidelines to determine the relative rank of a release in comparison with others. The prioritization methods described herein require that some estimates of quantities of each radionuclide or radionuclide class released to the environment be available. In some cases, these data are not available for all facilities or for all years of operations at LANL.

The prioritization of releases from LANL has been problematic. During the Manhattan Project era and continuing well into the post-1946 AEC era, LANL did not measure many of its release points, and did not systematically archive and compile effluent data. No effort has been made to characterize the magnitude of the releases from non-point source emissions that have been shown to be particularly important at other DOE sites, such as Rocky Flats. Unlike at most DOE sites, the available effluent data from LANL are well-documented for only the post Clean Air Act (post-1969) era. Only summary-level information for certain facilities is reported in LANL's compilations of available data prior to this period. In addition, potentially important release sources, such as D-Building (Fig. 17-1), which housed

plutonium processing during World War II and remained active until around 1953, were not subjected to stack sampling programs, and have no effluent data available.

Fig. 17-1. The earliest plutonium processing at LANL was conducted in this facility, known as D-Building. Airborne effluents through approximately 85 rooftop vents were unmonitored and largely unfiltered. Photograph from the late 1940s.

Unlike at other AEC/DOE site studied thus far with regard to historical releases, there was no comprehensive compilation of environmental release data available at LANL to use to establish a simple, initial prioritization. The best available compilation was assembled in the early 1970s to support the first site-wide final environmental impact statement (FEIS) that LANL published in response to the requirements of the Clean Air Act (USDOE, 1979). The LAHDRA team found that compilation to have numerous errors and omissions, however. Nonetheless, this preliminary prioritization has used data assembled for that report, as well as other information, such as estimates of the quantities of uranium expended in explosive test shots, to augment the LANL compilation.

Prioritization of Airborne Radionuclide Releases

LANL operations began in 1943 and have continued to the present. In the early years, radiation science, environmental science, and occupational health were disciplines in their infancy. As time progressed, LANL has, through its own volition and through public and governmental pressure, increased its monitoring, record keeping and reporting.

Data Sources

Airborne radionuclide effluent information for LANL was derived from the following data sources:

CMR-12 and H-1 monthly reports. These reports were the source of stack concentration data used to reconstruct plutonium releases for DP West Building 12 for the period 1948 – 1960. They were also the source of the plutonium release data for DP West Building 146 for 1959 and 1960. The 1959 data for Building 146 began in July of that year.

LANL Environmental Surveillance Reports from 1971-1996. These reports were issued either semi-annually or annually dating back to 1971. They were the principal source of the airborne radionuclide release data for 1973 forward.

(Andrews, 1973) – "Joe Graf Binders" 1 and 2– Two binders of documents assembled by LANL Environment, Safety, and Health (ES&H) staff for group leader Joe Graf in the early 1970s that document releases from LANL before 1973. This effort was undertaken to support a draft site-wide FEIS. The FEIS was published in 1979. The documents assembled in these binders include records of room air concentrations, stack monitoring data, ES&H reports, and miscellaneous memos.

(Dummer et al., 1996) – A detailed study of all the RaLa shots conducted in Bayo Canyon at Los Alamos and the quantities of RaLa involved in those explosives tests from 1944 to 1962.

(Drake and Eyster, 1971) – A memo that details estimated quantities of uranium that were expended in dynamic testing at LANL from 1944 to 1970.

(Jordan and Black, 1958) – An article in the *American Industrial Hygiene Association Journal* that discusses LANL's airborne radioactive effluents. This work is one of the most important early studies of LANL plutonium releases; LANL considers it to be the best-available scientific data concerning possible early emissions. As discussed later in this chapter, the LAHDRA project team disagrees with that assessment, although it does recognize some value in that work.

Summary of Results for Prioritization of Airborne Radionuclide Releases

Throughout LANL's existence, many operations involving radionuclides have been performed, and effluents containing various radioactive constituents have been released. This section outlines the Priority Indices (PI) calculation for airborne releases of the following materials, which were selected to be consistent with LANL's reporting practices for airborne radioactive effluents:

- Plutonium
- Uranium
- Tritium
- Radioactive Lanthanum (RaLa)

- Mixed Fission Products (MFP)
- Mixed Activation Products (MAP)
- Iodine-131

PIs for airborne radionuclide releases were calculated by computing the air volume (in liters, L) required to dilute the annual activity released to a concentration equal to the worst-case maximum effluent concentration, (maximum permissible concentration or MPC) per the current NRC regulations (USNRC, 2010). The PI does not consider environmental transport and dilution, and is intended only to be a simple means of evaluating the relative priority of LANL's airborne radionuclide releases. Although the lowest available (most conservative) maximum effluent concentration is used in the PI, it does not otherwise address the chemical or physical form of the material released. It also does not consider transport decay, meaning that it may tend to overstate the importance of short-lived materials.

The data sources summarized above served as the basis for all of the airborne radionuclide release data that follow. The LAHDRA team did not independently evaluate or reconstruct the reported airborne release data. Release data were used as reported by LANL. A summary of the available release data, by radionuclide, is provided below.

Effluent Data for Plutonium: Plutonium data were obtained for the calendar years 1948 through 1996 from the data sources described above. Release estimates are not available for D-Building, which began operations in late 1943/early 1944, and remained in use until around 1953. It is important to note that no airborne effluent data were included in LANL compilations for the years 1944 through 1947. Furthermore, the releases from DP Site reported by LANL for 1948, 1949, and 1950 are apparently based on simple estimates first made by Jordan and Black using methods that are not well documented (Jordan and Black, 1958). In addition, there were other stacks beyond the four main stacks at Building 12 at DP West that were monitored, however, these data were not included in FEIS documentation, and were not compiled as part of the LAHDRA project.

Airborne release data for plutonium were obtained from monthly reports of the CMR-12 and H-1 monitoring sections, the data compiled for the 1979 FEIS, and the annual environmental surveillance reports. Earlier versions of this report utilized a study by LANL's industrial hygiene group in 1955 and 1956 and reported by Edwin C. Hyatt in 1956 (Hyatt, 1956). In that study, stack concentrations were measured with improved, isokinetic stack sampling systems that were operated alongside the original systems (Hyatt, 1955). After six months of sampling, results were compared, and correction factors were determined and applied to releases previously reported for 1948-1955. Past that point, the improved sampling system was used.

Comments by LANL staff on the earlier LAHDRA report indicated that the Hyatt work was in error, and so that data is not used in this version of the LAHDRA report. When the old and new systems are compared, daily measurements do not agree well; however, when all of the data from the test period is averaged, the two systems, on average, agree. Since the new system was isokinetic, it is believed to be a better measurement, and the old system likely suffered from significant sampling errors and variability. In general, the results are within a factor of ten; however, individual measurements were found to differ by as much as a factor of 2900. LANL has been unable to find drawings of either stack system; however, photographs of the old stack sampling system indicate that it was attached to a small hinged door located on a rectangular transition section of the plenum upstream of the main stack blowers. No sample nozzle was likely used, and that the sample was taken at right angles to the main flow and near the wall.

Because of the changes in air sampling technology around the 1950s and 1960s, it was necessary to apply adjustments to results from earlier sampling efforts to account for what was later shown to be problems with the older technology. Much of this work was performed by LANL. Two types of adjustments were applied to the data: sample line loss correction factor and a filter dust loading and burial correction factor, The LAHDRA team applied these factors as appropriate in the prioritization effort.

All airborne plutonium releases reported for 1948 through 1975 were adjusted by the LAHDRA team using a sample line loss correction factor equal to five for the period 1948-1958. A factor of two was applied for the period 1959-1975 for all releases except those from DP West Building 12. These factors were selected based on analyses performed by LANL staff (Fuehne, 2008). The reduction of the line loss correction factor starting in 1959 took into account the fact that a single stage of high efficiency particulate air (HEPA) filters was added to the combined process exhaust system at DP West in 1959 (Maraman et al., 1975), and that the particle size distribution in that exhaust stream likely shifted toward smaller particles. The LAHDRA team extended this logic to the other sources of airborne plutonium releases for the 1959 - 1975 period (e.g. CMR Building). However, the factor of five was maintained for releases from DP West Building 12 for the entire period 1948 – 1975 because Building 12 exhaust was not part of the HEPA filter exhaust system.

A filter dust loading and burial correction factor of 2.33 was also applied to plutonium release totals reported by LANL for 1948 through 1959 based on assessments performed by LANL staff (Fuehne, 2008). Larger particle sizes may not have been properly sampled. A burial factor of 1.6 measured by LANL staff in the 1970s was applied to data starting in 1959, since the addition of HEPA filtration likely reduced dust loading on the sample filter. As for the line loss factor, this reduction in the burial correction factor was not applied for releases from DP West Building 12. Rather, the factor of 2.33 was used for all Building 12 releases for the period 1948 – 1975.

These line loss and filter burial corrections might also be appropriate for years following 1975, but have not been applied in this assessment. Thus, these data may be understated for some of those years by a factor of 3.2. We have not found any documentation identifying when LANL first applied these correction factors, but were able to determine that routine application was evident by the 1980s.

A calculation was completed in October, 2006 that analyzed the reported releases from DP West for calendar year 1957, using the actual daily stack sampling and analysis reports. This calculation was compared with the LANL compilation (Andrews, 1973) that was the basis for asserted releases of plutonium from LANL. The LAHDRA team's analysis of the 1957 data revealed that 40% of all operating hours at DP West Site were not monitored; these unmonitored periods were mostly associated with weekends and holidays. A method for estimating the hours when the stacks were not monitored was therefore needed. The method that LANL used was likely conservative, in that it scaled from operating hours to estimate hours in which no stack measurement was made. The LAHDRA review of the 1957 data also showed that the simple assumptions originally made in the early 1970s, such as stack and sample stream flow rates, were used for all periods. These assumptions, however, do not appear to have always been appropriate. The air concentration and fallout tray data for the 37-d operating period during 1957 that Jordan and Black used (Jordan and Black, 1958) could also be used to benchmark air transport models for airborne release assessment from DP West Site. However, the LAHDRA project team has been unable to identify the 37-d period, and LANL staff have been unable to supply information about the Jordan and Black study beyond what is contained in the associated journal paper.

The maximum allowable effluent concentration used for calculating priority indices for plutonium releases was 2×10^{-14} μCi mL^{-1} from 10CFR20 Appendix B, Table 2.

Table 17-1 and Figure 17-2 present the estimated annual release totals (in μCi) and the corresponding priority indices (dilution volume in liters) for plutonium. The plutonium priority indices over the years of LANL operations range in magnitude from 10^{11} to 10^{17}.

Table 17-1: Airborne Plutonium Release Estimates and Priority Indices[a]

Year	Release (µCi)	Priority Index (L)
1948	6.88E+05*	3.44E+16*
1949	4.39E+06*	2.19E+17*
1950	2.88E+06*	1.44E+17*
1951	4.98E+05*	2.49E+16*
1952	9.39E+05*	4.70E+16*
1953	5.64E+05*	2.82E+16*
1954	3.38E+05*	1.69E+16*
1955	1.30E+06*	6.48E+16*
1956	1.19E+06	5.95E+16
1957	1.18E+06	5.89E+16
1958	1.29E+06	6.46E+16
1959	2.81E+06	1.41E+17
1960	6.82E+05	3.41E+16
1961	5.15E+04	2.57E+15
1962	3.61E+04	1.80E+15
1963	6.36E+04	3.18E+15
1964	1.74E+04	8.68E+14
1965	1.78E+04	8.88E+14
1966	3.03E+04	1.52E+15
1967	8.54E+04	4.27E+15
1968	3.21E+04	1.60E+15
1969	7.80E+04	3.90E+15
1970	6.87E+04	3.43E+15
1971	5.89E+04	2.95E+15
1972	5.05E+04	2.52E+15
1973	2.79E+04	1.40E+15
1974	2.54E+03	1.27E+14
1975	7.88E+02	3.94E+13
1976	6.79E+01	3.40E+12
1977	1.27E+02	6.37E+12
1978	1.12E+02	5.62E+12
1979	1.08E+03	5.42E+13
1980	7.47E+02	3.73E+13
1981	5.69E+01	2.84E+12
1982	1.12E+02	5.59E+12
1983	1.13E+02	5.65E+12
1984	1.40E+02	6.99E+12
1985	2.13E+02	1.07E+13
1986	2.07E+02	1.04E+13
1987	7.28E+01	3.64E+12
1988	7.24E+01	3.62E+12
1989	4.55E+01	2.27E+12
1990	2.58E+01	1.29E+12
1991	3.69E+01	1.84E+12
1992	1.24E+01	6.18E+11
1993	6.44E+00	3.22E+11
1994	1.25E+01	6.24E+11
1995	6.50E+01	3.25E+12
1996	2.00E+01	1.00E+12

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000. *Partial or incomplete data.

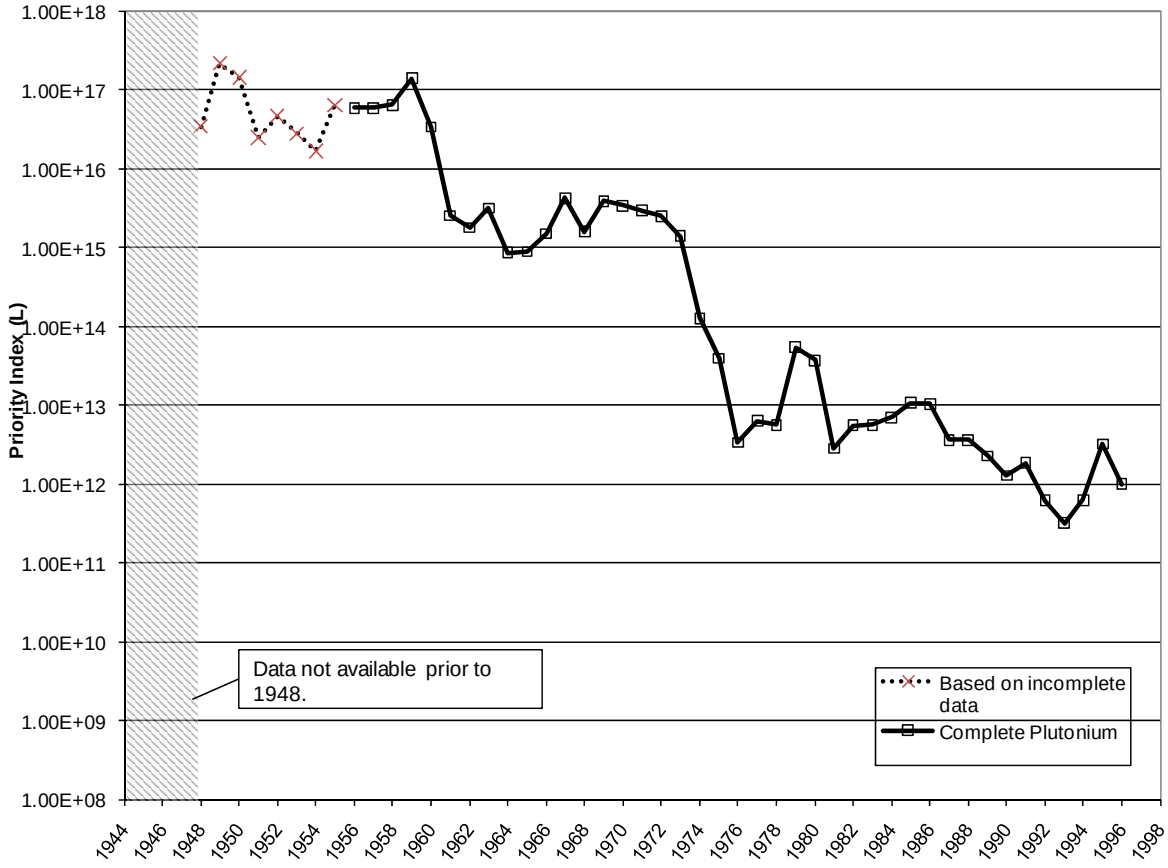


Figure 17-2: Airborne Plutonium Release Estimates and Priority Indices

Effluent Data for Uranium: Airborne uranium release data are presented for 1949 – 1996. The uranium releases are a combination of material expended in dynamic experiments (test shots driven by high explosives) and releases from routine operations in areas such as TA-3 and TA-21. Data sources for uranium release data were taken from Drake and Eyster (1971), the data compiled for the 1979 FEIS, and the annual environmental surveillance reports.

For the period 1949 through 1966, the quantities of uranium expended in dynamic experiments at LANL were obtained from the report "Uranium Dispersed by Experimental 'Shots' at Los Alamos" (Drake and Eyster, 1971). Uranium expenditures for 1967 through 1972 were obtained from the data compilations for the 1979 FEIS, and the expenditures for 1973 forward were taken from LANL environmental surveillance reports. These environmental surveillance reports, however, did not include uranium expenditures for 1974 and 1975. The expenditures for these years were therefore assigned a value of 1,000 kg each, reflecting the average expenditure value for the other years during the period 1970 through 1979.

All of the uranium expenditures from dynamic testing activities are reported in terms of mass. The conversion from mass to activity depended on whether the uranium involved was natural or depleted. Per Drake and Eyster (1971), all of the expenditures for 1949 through 1955 were assumed to be natural uranium. All expenditures for 1956 forward were assumed to be depleted uranium. Natural uranium mass was converted to activity using the factor 6.72×10^{-7} Ci g^{-1}. For depleted uranium the conversion factor (specific activity) used was 5.14×10^{-7} Ci g^{-1}.

The majority of the uranium expended in a dynamic test was deposited locally. Because a small fraction of the material could potentially be carried offsite, however, an "aerosolization fraction" was applied to the quantity of uranium expended in a given year to calculate the airborne activity potentially carried offsite. The fraction used was 10%, per the LANL report "Aerosolized U and Be from LASL Dynamic Experiments" (Dahl and Johnson, 1977).

Uranium releases from routine operations are included in the airborne release estimate for 1952 forward. The estimates for 1949 through 1951 reflect only the firing site expenditures. The data compilation from the 1979 FEIS was used to estimate the contributions of routine operations to uranium releases for 1952 through 1972. Data from the environmental surveillance reports was used for releases from 1973 forward. All operational releases from 1952 through 1975 have been adjusted to account for sample line loss and filter burial, in the same manner as was done for plutonium release data. These corrections were not applied for releases associated with dynamic experiments, since those estimates are not based on measurements.

The maximum allowable effluent concentration used for calculating priority indices for airborne uranium releases was 6×10^{-14} μCi mL^{-1}. This value is for ^{235}U as taken from 10CFR20 Appendix B, Table 2. Table 17-2 and Figure 17-3 present the estimated annual release totals and the corresponding priority indices for airborne uranium. The priority indices for uranium during the years of LANL operations range in magnitude from 10^{13} to 10^{16}.

Table 17-2: Airborne Uranium Release Estimates and Priority Indices[a]

Year	Release (µCi)	Priority Index (L)
1948	--	--
1949	1.92E+05*	3.19E+15
1950	1.01E+06*	1.68E+16
1951	4.54E+05*	7.56E+15
1952	3.93E+05*	6.55E+15
1953	3.63E+05*	6.05E+15
1954	3.47E+05*	5.79E+15
1955	2.83E+05*	4.72E+15
1956	1.65E+05*	2.74E+15
1957	2.30E+05*	3.83E+15
1958	2.19E+05*	3.65E+15
1959	1.12E+05*	1.86E+15
1960	1.39E+05*	2.32E+15
1961	1.06E+05*	1.77E+15
1962	1.43E+05*	2.39E+15
1963	1.98E+05*	3.29E+15
1964	1.47E+05*	2.45E+15
1965	1.42E+05*	2.37E+15
1966	1.99E+05*	3.32E+15
1967	2.13E+05	3.56E+15
1968	1.32E+05	2.20E+15
1969	1.43E+05	2.38E+15
1970	4.60E+04	7.67E+14
1971	8.81E+04	1.47E+15
1972	4.95E+04	8.26E+14
1973	3.68E+04	6.14E+14
1974	5.40E+04	9.00E+14
1975	5.43E+04	9.06E+14
1976	5.39E+04	8.99E+14
1977	8.27E+04	1.38E+15
1978	7.10E+04	1.18E+15
1979	3.01E+04	5.02E+14
1980	4.61E+04	7.68E+14
1981	5.71E+04	9.52E+14
1982	5.58E+04	9.30E+14
1983	4.35E+04	7.26E+14
1984	4.44E+04	7.40E+14
1985	2.77E+04	4.61E+14
1986	1.11E+04	1.85E+14
1987	6.09E+03	1.02E+14
1988	1.59E+04	2.65E+14
1989	1.26E+04	2.10E+14
1990	4.71E+03	7.85E+13
1991	1.62E+04	2.70E+14
1992	2.56E+04	4.26E+14
1993	1.56E+04	2.60E+14
1994	6.08E+03	1.01E+14
1995	7.56E+03	1.26E+14
1996	9.05E+03	1.51E+14

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000. *Partial or incomplete data.

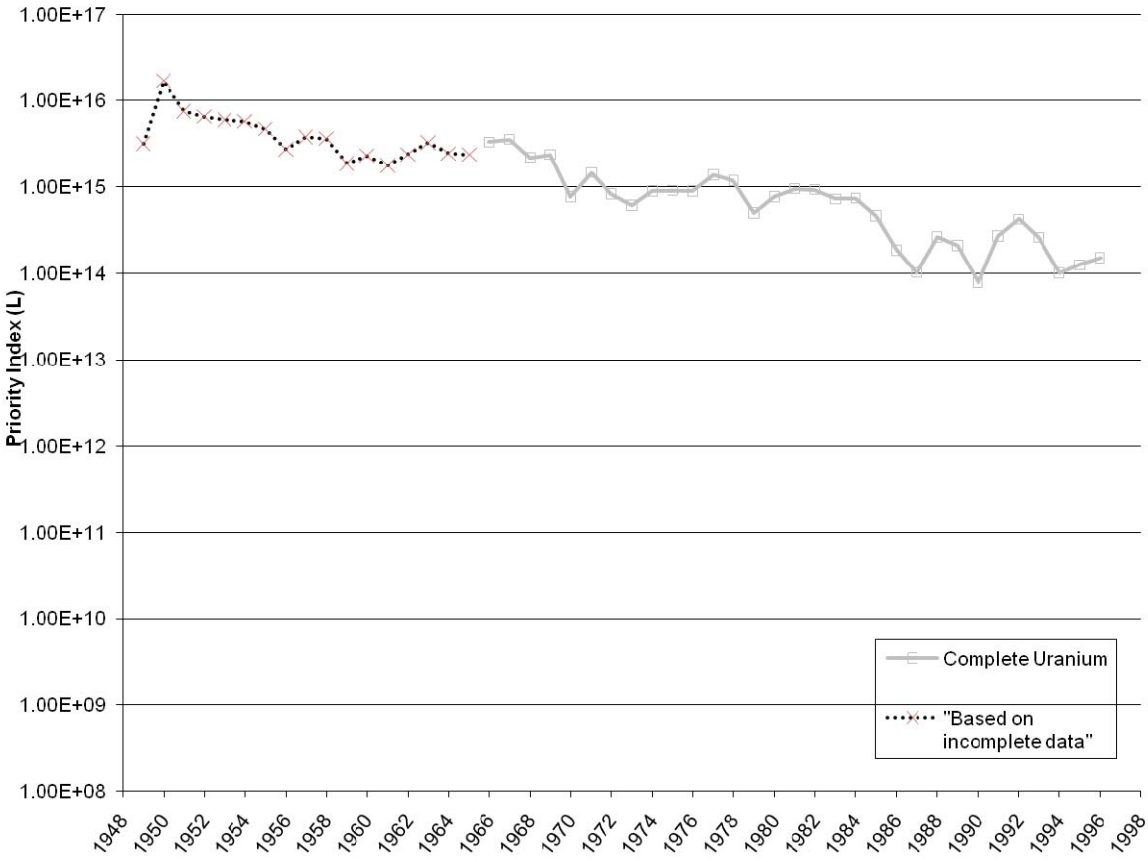


Fig. 17-3: Airborne Uranium Release Estimates and Priority Indices

Effluent Data for Tritium: Airborne release estimates for tritium are provided for 1967 through 1996. Tritium release data were obtained from the data compilations for the 1979 FEIS and the environmental surveillance reports. No correction factors were used for tritium release estimates. Much of the release data came from accountability data rather than stack release data. Estimates based on accountability data are typically conservative with respect to the true release, although none of the data used in this evaluation have been independently verified. The available stack release data were measured using Kanne Chamber detectors; therefore, sample line loss and filter burial correction were not applied. Tritium was used at LANL as far back as 1945, or possibly even 1944. More data are required to determine pre-1967 tritium releases at LANL. LAHDRA staff have found additional documents containing tritium release data associated with episodic releases before and after 1967, and have added them to the project information database, but these data are scattered across many documents, and have not yet been compiled or used to bound releases before 1967.

Based on the available data, the maximum allowable effluent concentration used for calculating priority indices for tritium releases was 1×10^{-7} μCi mL^{-1} from 10CFR20 Appendix B, Table 2. This value is for tritium oxide (tritiated water vapor), and thus may overstate the importance of tritium relative to other atmospheric releases, since many tritium releases at LANL involved tritium gas. Table 17-3 and Figure 17-4 present the estimated annual release totals and the corresponding priority indices for airborne tritium. The priority indices range in magnitude from 10^{12} to 10^{14}.

Table 17-3: Airborne Tritium Release Estimates and Priority Indices[a]

Year	Release (µCi)	Priority Index (L)
1948	--*	--
1949	--*	--
1950	--*	--
1951	--*	--
1952	--*	--
1953	--*	--
1954	--*	--
1955	--*	--
1956	--*	--
1957	--*	--
1958	--*	--
1959	--*	--
1960	--*	--
1961	--*	--
1962	--*	--
1963	--*	--
1964	--*	--
1965	--*	--
1966	--*	--
1967	2.79E+10	2.79E+14
1968	3.63E+10	3.63E+14
1969	3.46E+10	3.46E+14
1970	3.71E+10	3.71E+14
1971	1.03E+10	1.03E+14
1972	7.42E+09	7.42E+13
1973	6.13E+09	6.13E+13
1974	7.49E+09	7.49E+13
1975	3.28E+08	3.28E+12
1976	3.40E+09	3.40E+13
1977	3.56E+10	3.56E+14
1978	1.86E+10	1.86E+14
1979	1.50E+10	1.50E+14
1980	7.52E+09	7.52E+13
1981	7.22E+09	7.22E+13
1982	1.59E+10	1.59E+14
1983	7.89E+09	7.89E+13
1984	1.49E+10	1.49E+14
1985	8.64E+09	8.64E+13
1986	9.71E+09	9.71E+13
1987	3.17E+09	3.17E+13
1988	1.10E+10	1.10E+14
1989	1.44E+10	1.44E+14
1990	6.35E+09	6.35E+13
1991	4.72E+09	4.72E+13
1992	1.30E+09	1.30E+13
1993	1.45E+09	1.45E+13
1994	1.08E+09	1.08E+13
1995	1.01E+09	1.01E+13
1996	6.87E+08	6.87E+12

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000. *Releases known to occur but no stack monitoring data or compilation of data found.

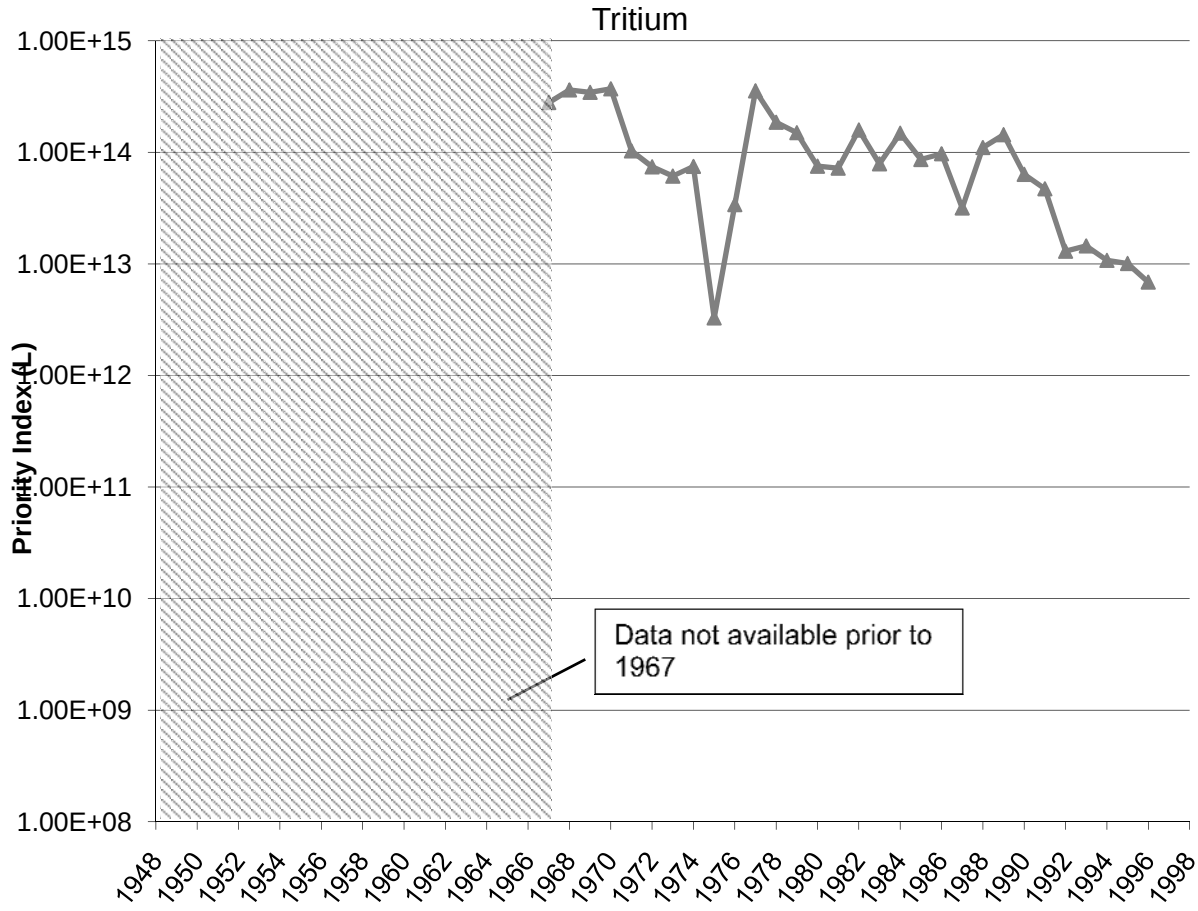


Fig 17-4: Airborne Tritium Release Estimates and Priority Indices

Effluent Data for Radioactive Lanthanum (RaLa): Airborne release estimates for RaLa are presented for 1944 through 1960. The RaLa program was active until March, 1962; however, later tests were conducted in such a manner that the RaLa source remained intact. There were therefore no releases associated with these tests after 1960. Also, there were no RaLa shots performed in 1951.

LANL personnel conducted a dose reconstruction of LANL's RaLa testing program, including a source term evaluation (Dummer et al., 1996). The LAHDRA team used the data from this reconstruction to estimate annual RaLa airborne releases, and applied an aerosolization fraction of 10% to the quantities of RaLa involved in test shots (as was done for uranium) in order to estimate the airborne activity expended in dynamic tests that may potentially have been carried to offsite individuals.

The maximum allowable effluent concentration used for calculating priority indices for RaLa releases was 2×10^{-9} μCi mL^{-1} for ^{140}La from 10CFR20 Appendix B, Table 2. Table 17-4 and Figure 17-5 present the estimated annual release totals and the corresponding priority indices for airborne RaLa. The priority indices range in magnitude from 10^{13} to 10^{15}.

Table 17-4: Airborne RaLa Release Estimates and Priority Indices[a,b]

Year	Release (μCi)	Priority Index (L)
1944	1.11E+08	5.56E+13
1945	1.84E+09	9.18E+14
1946	2.06E+09	1.03E+15
1947	2.27E+09	1.14E+15
1948	1.22E+09	6.12E+14
1949	2.83E+09	1.41E+15
1950	1.98E+09	9.89E+14
1951	0.00E+00	0.00E+00
1952	6.37E+08	3.19E+14
1953	1.07E+08	5.33E+13
1954	1.56E+09	7.79E+14
1955	4.08E+09	2.04E+15
1956	3.60E+09	1.80E+15
1957	1.74E+09	8.68E+14
1958	9.85E+08	4.92E+14
1959	8.32E+08	4.16E+14
1960	4.09E+08	2.04E+14
1961	0.00E+00	0.00E+00
1962	0.00E+00	0.00E+00

[a] The RaLa program ended in 1962. There were no releases in 1950, 1961, or 1962. [b] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

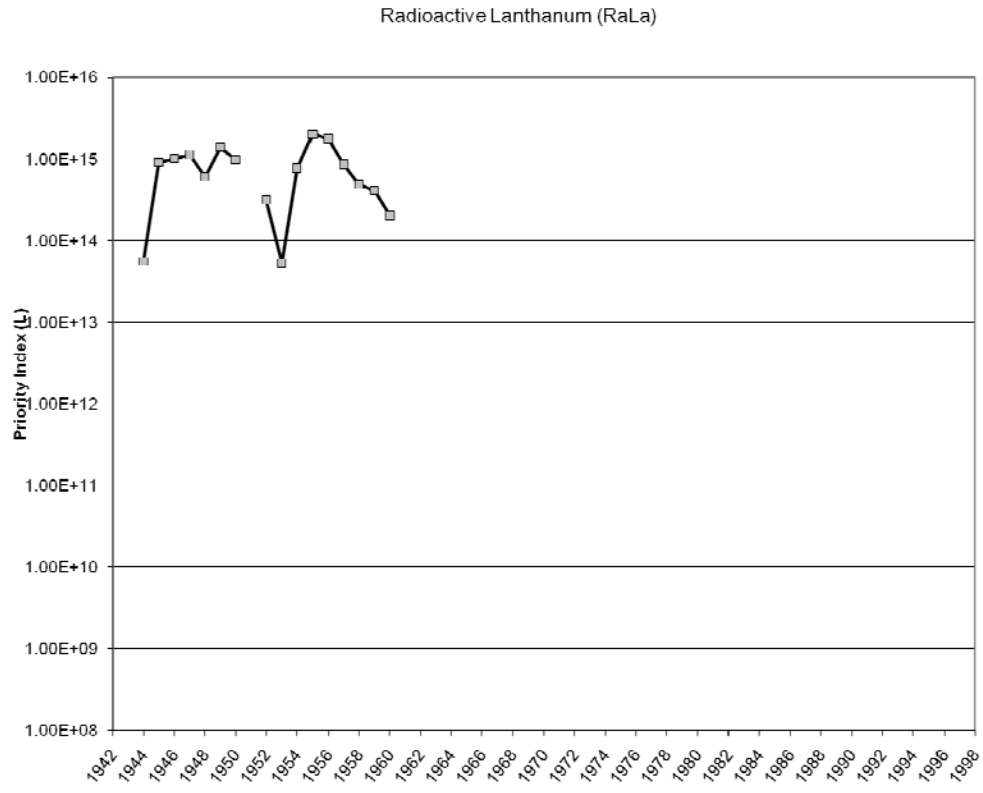


Fig. 17-5: Airborne RaLa Release Estimates and Priority Indices

Effluent Data for Mixed Fission Products (MFP): Estimates for airborne releases of MFP are presented for 1961 through 1994. The data for 1961 through 1972 came from the 1979 FEIS documentation. The data for 1973 forward came from the environmental surveillance reports. Mixed fission product releases at LANL came from reactor operations (primarily in TA-2, although for a brief period the UHTREX reactor in TA-52 was also included), from hot cell operations with irradiated nuclear materials (in TA-3, TA-21, and TA-48), and from waste disposal operations (at TA-50). MFP is a generic term, however; as of 1973, LANL was applying a definition for reporting purposes under which MFP releases were considered as four month-decayed fission products at the time of release (Valentine, 1973). The "primary biologically significant nuclides" were therefore ^{90}Sr and ^{137}Cs.

As for the other airborne particulate releases, the release data for MFP have been adjusted by applying correction factors for sample line loss and filter burial through 1975. The MFP data include a significant release reported for the UHTREX reactor in 1969. Further study is needed to determine if the reported release included noble gases or other materials for which applying these correction factors would be inappropriate. Likewise, the maximum allowable air concentration used to compute the PI for this release might require adjustment if a large fraction of the activity was found to be from short-lived radionuclides.

The maximum allowable effluent concentration used to calculate priority indices for MFP was 1×10^{-10} $\mu Ci\ mL^{-1}$. This value was derived from the average of the allowable air concentration limits for ^{137}Cs (2×10^{-10} $\mu Ci\ mL^{-1}$) and soluble ^{90}Sr (3×10^{-11} $\mu Ci\ mL^{-1}$) from 10CFR20 Appendix B, Table 2. The soluble concentration limit is used for ^{90}Sr since the material of concern is fission products.

Table 17-5 and Figure 17-6 present the estimated annual release totals and the corresponding priority indices for airborne MFP. The priority indices range in magnitude from 10^9 to 10^{13}.

Table 17-5: Airborne MFP Release Estimates and Priority Indices[a]

Year	Release (µCi)	Priority Index (L)
1948	--*	--
1949	--*	--
1950	--*	--
1951	--*	--
1952	--*	--
1953	--*	--
1954	--*	--
1955	--*	--
1956	--*	--
1957	--*	--
1958	--*	--
1959	--*	--
1960	--*	--
1961	5.76E+03	5.76E+10
1962	1.38E+06	1.38E+13
1963	8.61E+04	8.61E+11
1964	7.10E+04	7.10E+11
1965	9.60E+03	9.60E+10
1966	1.15E+04	1.15E+11
1967	5.78E+04	5.78E+11
1968	5.24E+04	5.24E+11
1969	4.16E+08	4.16E+15
1970	3.96E+04	3.96E+11
1971	1.45E+04	1.45E+11
1972	3.11E+04	3.11E+11
1973	4.49E+04	4.49E+11
1974	4.40E+03	4.40E+10
1975	3.04E+03	3.04E+10
1976	1.67E+03	1.67E+10
1977	2.76E+03	2.76E+10
1978	1.61E+03	1.61E+10
1979	1.56E+03	1.56E+10
1980	2.19E+03	2.19E+10
1981	1.54E+03	1.54E+10
1982	1.18E+03	1.18E+10
1983	8.43E+02	8.43E+09
1984	1.62E+03	1.62E+10
1985	1.25E+03	1.25E+10
1986	2.57E+03	2.57E+10
1987	1.29E+03	1.29E+10
1988	1.15E+03	1.15E+10
1989	4.35E+05	4.35E+12
1990	1.08E+03	1.08E+10
1991	1.10E+03	1.10E+10
1992	2.75E+03	2.75E+10
1993	1.36E+03	1.36E+10
1994	4.35E+02	4.35E+09

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000. *Releases are known to have occurred but data not found

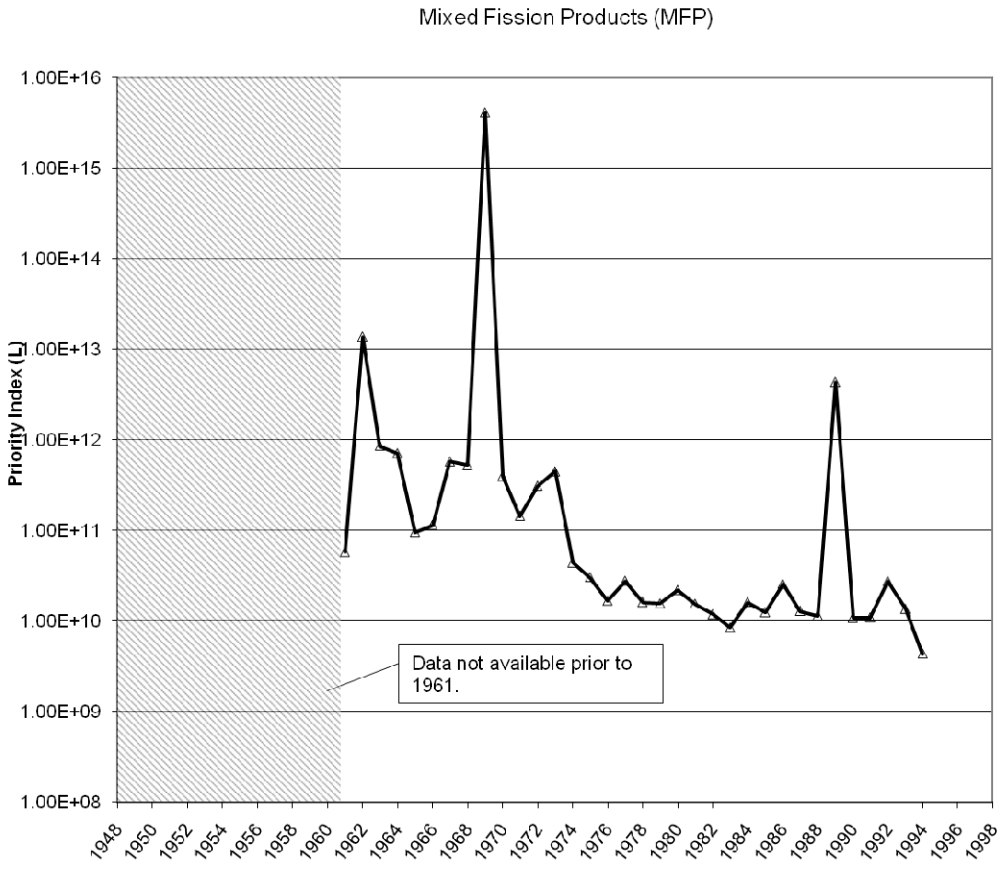


Fig. 17-6: Airborne MFP Release Estimates and Priority Indices

Effluent Data for Mixed Activation Products (MAP): MAP make up the largest portion of LANL's airborne radioactive releases for 1979 through 1995. Reactors and large accelerators are the main producers of MAP radionuclides. At LANL, then, the majority of the MAP would come from TA-53 and the Los Alamos Meson Physics Facility (LAMPF), now called the Los Alamos Neutron Science Center (LANSCE). Although LAMPF started operating in 1971, no effluent data were found for MAP prior to 1976.

MAP releases are reported in the annual environmental surveillance reports for 1976 forward. For 1976 through 1981, these releases are reported as gaseous mixed activation products (G/MAP) only, consisting of ^{11}C, ^{13}N, and ^{15}O. In 1983 LANL began including particulate or vapor activation products (P/VAP) in the releases reported for TA-53. The main constituents of the P/VAP activity were ^{192}Au (for particulates) and ^{195}Hg (for vapor). The definition of G/MAP was expanded in 1983 to include ^{11}C, ^{13}N, ^{14}O, ^{15}O, and ^{41}Ar. The ^{41}Ar was only 0.4% of the G/MAP activity. TA-53 releases were reported in terms of total activity for G/MAP and P/VAP for the period 1983 through 1991. In 1992, LANL began reporting G/MAP activity on a nuclide specific basis, including ^{10}C, ^{11}C, ^{13}N, ^{16}N, ^{14}O, and ^{15}O. P/VAP

activity was still reported as a lump sum. TA-53 releases were reported in this manner through 1994. In 1995, LANL switched back to reporting G/MAP releases on a lump sum basis. It also revised the definition of particulate releases to comprise particulate/vapor activation and fission products (P/VAFP), excluding ^{90}Sr. ^{90}Sr releases were reported separately, though there was no such release associated with TA-53. In 1996, LANL instead began to report airborne releases on a site-wide basis (and only in graphical form), so only G/MAP data were provided.

The particulate contribution to the total release of airborne activity from TA-53 was trivial throughout the entire 1982- 1996 period. The LAHDRA team nevertheless included these releases in its compiled totals in order to be complete. Data were compiled from the environmental surveillance reports for 1976 through 1996. No correction factors for effects, such as sample line loss or filter burial, have been applied to these data, since these would not be appropriate for gaseous releases measured via an in-stack ion chamber. Further, the date range is beyond that to which the LAHDRA team has applied such corrections to particulate release data.

The maximum allowable effluent concentration used to calculate priority indices for MAP was 1×10^{-7} $\mu Ci\ mL^{-1}$, per Footnote 2 to 10CFR20 Appendix B. Table 17-6 and Figure 17-7 present the estimated annual release totals and the corresponding priority indices for airborne MAP. The priority indices range in magnitude from 10^{13} to 10^{15}.

Table 17-6: Airborne MAP Release Estimates and Priority Indices[a]

Year	Release (µCi)	Priority Index (L)
1948	--	--
1949	--	--
1950	--	--
1951	--	--
1952	--	--
1953	--	--
1954	--	--
1955	--	--
1956	--	--
1957	--	--
1958	--	--
1959	--	--
1960	--	--
1961	--	--
1962	--	--
1963	--	--
1964	--	--
1965	--	--
1966	--	--
1967	--	--
1968	--	--
1969	--	--
1970	--	--
1971	--	--
1972	--*	--
1973	--*	--
1974	--*	--
1975	--*	--
1976	5.89E+09	5.89E+13
1977	4.72E+10	4.72E+14
1978	1.16E+11	1.16E+15
1979	1.19E+11	1.19E+15
1980	1.46E+11	1.46E+15
1981	3.52E+11	3.52E+15
1982	2.51E+11	2.51E+15
1983	4.64E+11	4.64E+15
1984	7.37E+11	7.37E+15
1985	1.26E+11	1.26E+15
1986	1.12E+11	1.12E+15
1987	1.50E+11	1.50E+15
1988	1.21E+11	1.21E+15
1989	1.56E+11	1.56E+15
1990	1.23E+11	1.23E+15
1991	5.72E+10	5.72E+14
1992	7.16E+10	7.16E+14
1993	3.19E+10	3.19E+14
1994	5.00E+10	5.00E+14
1995	4.36E+10	4.36E+14
1996	1.12E+10	1.12E+14

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.* LAMPF started in June of 1972. No data found for the early period.

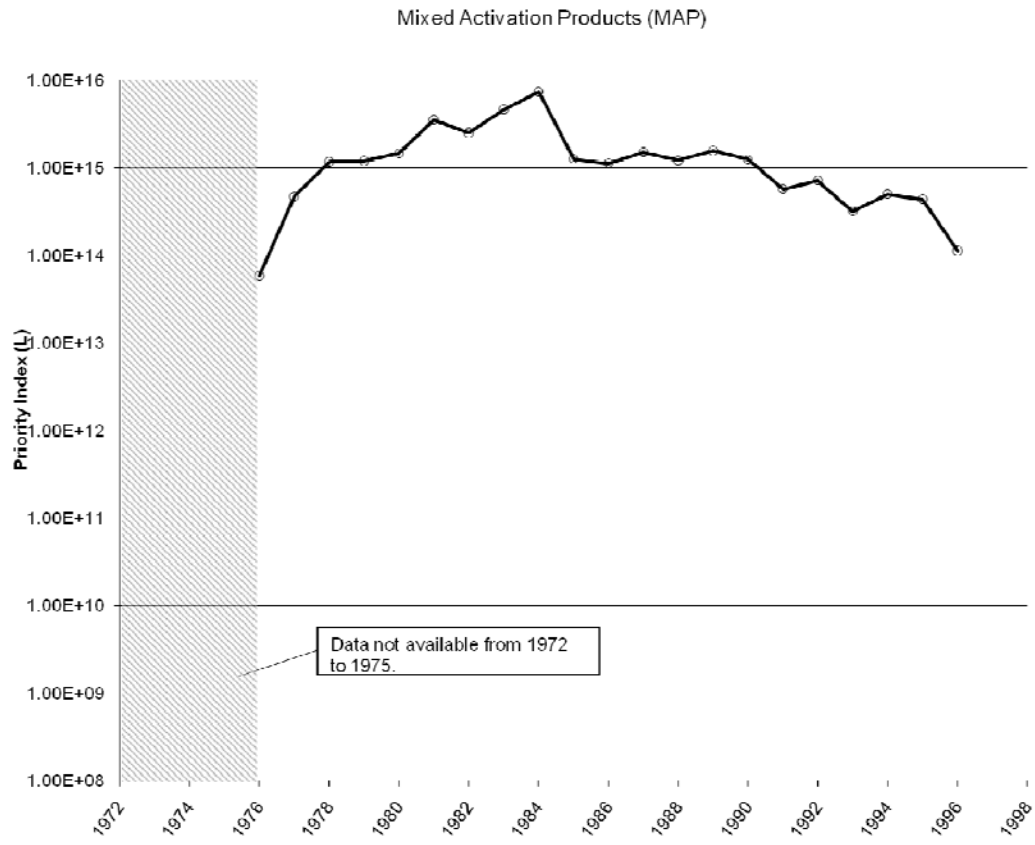


Fig. 17-7: Airborne MAP Release Estimates and Priority Indices

Effluent Data for ^{131}I: Airborne release estimates for ^{131}I are presented for 1967 through 1986. Release data were obtained from the data compiled for the 1979 FEIS (for 1967 through 1972) and from the annual environmental surveillance reports (for 1973 through 1986). For 1967 through 1972, the ^{131}I releases are attributed specifically to CMR Building Wing 9. For 1973 forward, the releases are attributed more broadly to TA-3, though presumably the source of the releases is still CMR Building Wing 9.

No correction factors were applied to ^{131}I data. The maximum allowable effluent concentration used to calculate priority indices for ^{131}I releases was 2×10^{-10} μCi mL^{-1} from 10CFR20 Appendix B, Table 2. Table 17-7 and Figure 17-8 present the estimated annual release totals and the corresponding priority indices for airborne MAP. The priority indices range in magnitude from 10^8 to 10^{10}.

Table 17-7: Airborne ^{131}I Release Estimates and Priority Indices[a,b]

Year	Release (µCi)	Priority Index (L)
1948	--*	--
1949	--*	--
1950	--*	--
1951	--*	--
1952	--*	--
1953	--*	--
1954	--*	--
1955	--*	--
1956	--*	--
1957	--*	--
1958	--*	--
1959	--*	--
1960	--*	--
1961	--*	--
1962	--*	--
1963	--*	--
1964	--*	--
1965	--*	--
1966	--*	--
1967	1.20E+04	6.00E+10
1968	1.00E+04	5.00E+10
1969	1.50E+04	7.50E+10
1970	5.00E+03	2.50E+10
1971	6.95E+03	3.48E+10
1972	7.40E+03	3.70E+10
1973	4.20E+03	2.10E+10
1974	5.00E+03	2.50E+10
1975	1.40E+03	7.00E+09
1976	3.00E+02	1.50E+09
1977	8.80E+01	4.40E+08
1978	8.10E+01	4.05E+08
1979	1.58E+02	7.90E+08
1980	9.40E+01	4.70E+08
1981	4.40E+01	2.20E+08
1982	7.85E+02	3.93E+09
1983	8.30E+01	4.15E+08
1984	7.30E+01	3.65E+08
1985	1.46E+02	7.30E+08
1986	3.80E+01	1.90E+08

[a] ^{131}I releases are not included in LANL's annual airborne emissions summaries after 1986. [b] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000. *Further investigation is needed to determine other sources of airborne ^{131}I releases prior to 1967 or after 1986.

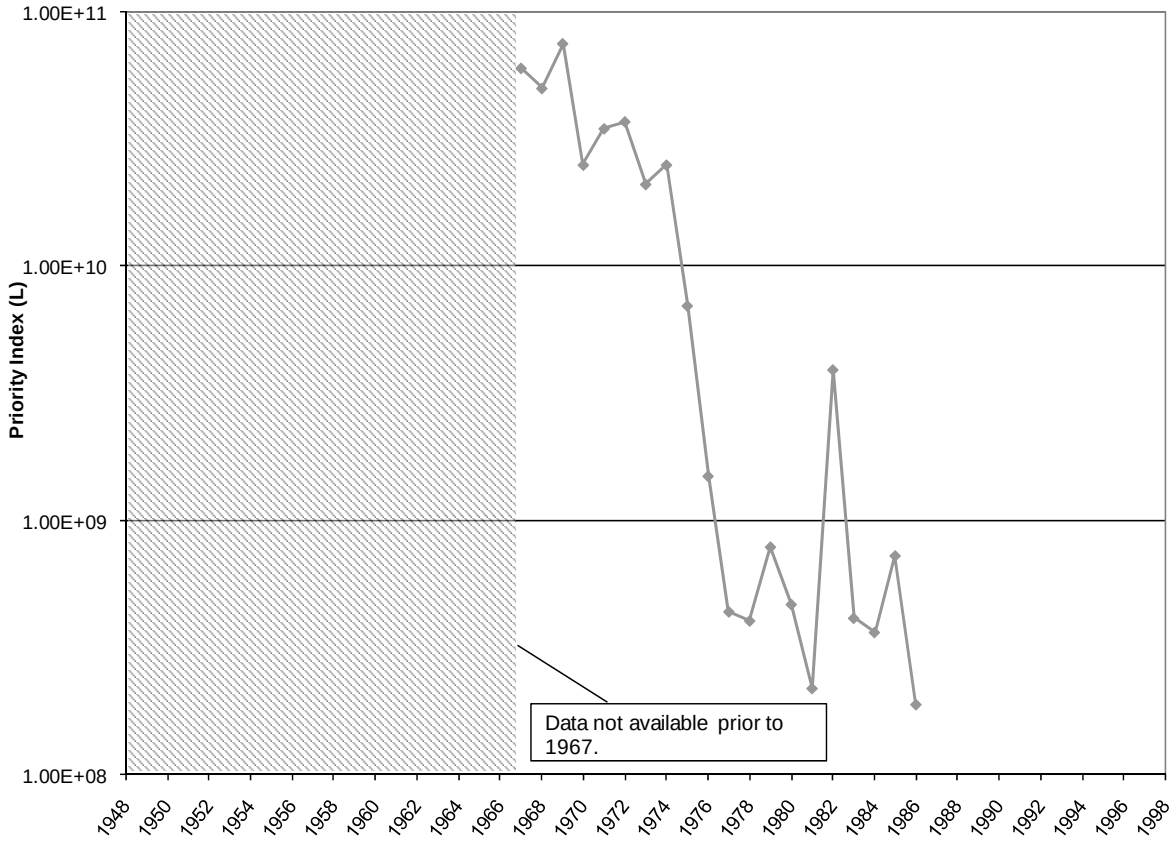


Fig. 17-8: Airborne ^{131}I Release Estimates and Priority Indices

Fig. 17-9 presents a combined plot of annual priority index values for airborne radionuclide releases from LANL facilities. It is important to emphasize that the purpose of the figure is to compare priority index values between radionuclides for years for which data were available. As noted in the previous sections, the lack of a priority index value does not necessarily mean that releases did not occur. Table 17-8 presents a summary of the radionuclide classes with the highest priority indices for each period of LANL operations. RaLa releases show the highest priority for the period prior to 1948 by default, since release estimates for other nuclides are not readily available for this period.

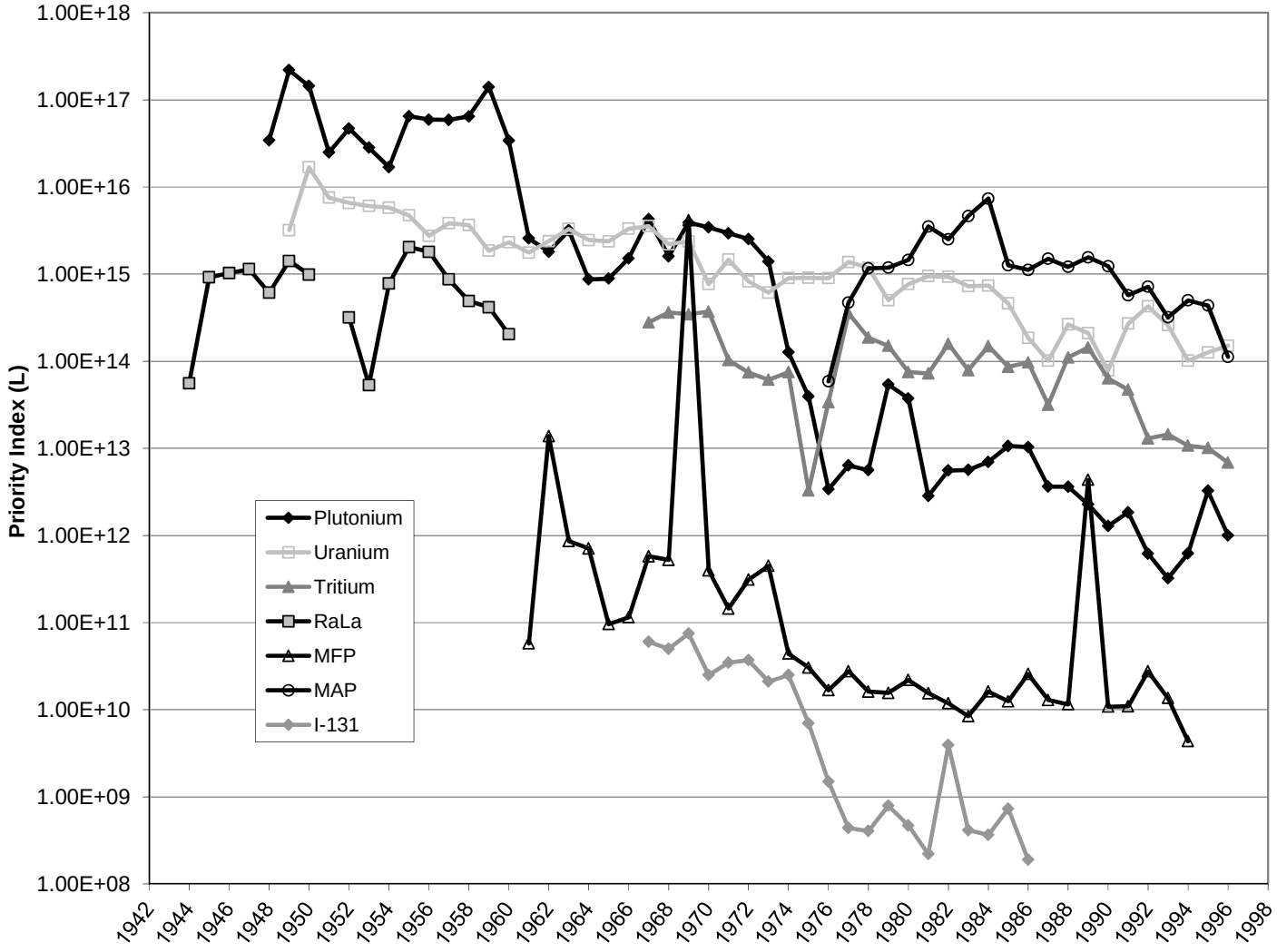


Figure 17-9. Priority Indices for Airborne Radionuclide Releases*

* Priority indices shown in this figure are limited to years for which data are available.

Table 17-8. Classes of Airborne Radionuclides with Highest Priority Indices for Each Period of LANL Operations

Years	Radionuclide Class with Highest Priority Indices	Range of Annual Priority Indices (L)		
1944-1947	Radioactive Lanthanum	6×10^{13}	to	1×10^{15}
1948-1961	Plutonium	3×10^{15}	to	6×10^{16}
1962-1966	Uranium	2×10^{15}	to	3×10^{15}
1967	Plutonium	4×10^{15}	to	4×10^{15}
1968	Uranium	2×10^{15}	to	2×10^{15}
1969	Mixed Fission Products*	4×10^{15}	to	4×10^{15}
1970-1973	Plutonium	1×10^{15}	to	3×10^{15}
1974-1978	Uranium	9×10^{14}	to	1×10^{15}
1979-1995	Mixed Activation Products	3×10^{14}	to	5×10^{15}
1996	Uranium	2×10^{14}	to	2×10^{14}

*Due to the large release reported for the UHTREX reactor for this period. This result needs further study.

Conclusions regarding prioritization of airborne radionuclides

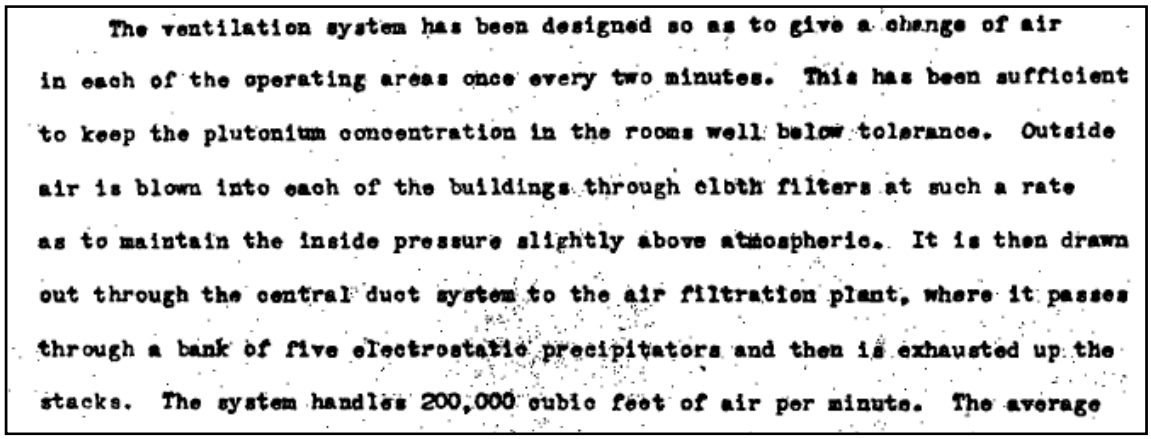
The LAHDRA prioritization of airborne radionuclide releases shows that, based on LANL compilations, plutonium and uranium were of primary concern until the late 1970s. From then, MAP radionuclides appear to have been of primary concern through 1995. However, in some cases, limited or no data were found in LANL compilations of releases for important nuclides, such as plutonium (D-Building data and pre-1948 data), polonium, tritium before 1967, all nuclides pre-1950, and non-point source emissions.

Comments and Issues

Data completeness - This prioritization effort was intended to present a "first look" at the scope and extent of radionuclides released at LANL over the years of its operation. Because LAHDRA's primary focus was to gather information, it expended limited effort toward entering or evaluating raw data identified in historical LANL documents. In general, the values LAHDRA used for the prioritization came from data previously compiled by LANL, with adjustments made as supported by available data. LAHDRA expended little effort analyzing the data from logbooks or other more detailed data sources. A significant amount of original release information (that is, lab measurements of a filter from a stack) for the 1950s and 1960s is available, though, and could be captured and analyzed if further evaluation of airborne releases is undertaken.

Plutonium releases – As is discussed elsewhere, the plutonium data presented here are lacking significant stack and non-stack (point and non-point) emissions. Source terms that are not addressed include stacks at D Building and stacks other than Building 12 at DP West for the pre-1956 era. In addition, there were significant fires in dumps or landfills used for disposing of contaminated waste and debris. Open fires

were used to burn contaminated oils at DP West. In the early years of LANL operations, some plutonium processing facilities, such as D-Building and the facilities at the DP West Site, were designed and operated with positive building pressure (LASL, 1947) (see Fig. 17-10 below). This feature could have resulted in significant unintentional release of building air out of doors and exit points other than the stacks. Similar release pathways could also have been active for large facilities such as LANSCE.



The ventilation system has been designed so as to give a change of air in each of the operating areas once every two minutes. This has been sufficient to keep the plutonium concentration in the rooms well below tolerance. Outside air is blown into each of the buildings through cloth filters at such a rate as to maintain the inside pressure slightly above atmospheric. It is then drawn out through the central duct system to the air filtration plant, where it passes through a bank of five electrostatic precipitators and then is exhausted up the stacks. The system handles 200,000 cubic feet of air per minute. The average

Fig. 17-10. Excerpt from a description of DP Site facilities and their ventilation systems (LASL, 1947).

Polonium - Significant quantities of polonium were used at LANL; however, no effluent data have been found for polonium, other than gross alpha measurements of buildings and stacks at DP East Site, where polonium and other materials were handled and processed. Due to polonium's shorter half-life, perhaps thousands of times more Ci of polonium then plutonium were used at LANL. In LANL's early years, plutonium was considered the most valuable substance on earth, and its use was strictly controlled. Once polonium became more readily available, however, it was not inventoried as closely as plutonium. Large amounts were used in nuclear weapon initiator explosive or destructive tests.

An annex to B-Building was built by the end of March, 1944. It held a 20-mm, remotely fired, anti-aircraft autocannon used for testing scaled-down versions of gun weapon components and gun initiators. It became operational in April, 1944, and housed and nearly 180 experiments were conducted by the end of September (about one per day), releasing unknown quantities of polonium and beryllium (LASL, 1944-1945). In August, 1944, a "coffin" was authorized; this box operated at negative pressure with a gas mask filtered exhaust, and was used to limit contamination of the machine gun and room during plutonium experiments. It was to be operational in September, 1944. While the LAHDRA team has addressed beryllium releases from the B-Building gun testing (See Chapter 20), polonium releases from this activity have not yet been addressed.

Pre-1967 tritium - There are no pre-1967 effluent data for tritium, although the LAHDRA team has identified documents that refer to significant tritium releases before 1967; in most cases they describe accidental or episodic releases (see Table 16-1). This release information is scattered across many historical documents, such as incident reports. The LAHDRA team did not identify any location holding any documents related to tritium releases before 1967. If more time could have been devoted to a directed search of records (some already captured by the LAHDRA team, and some not) for episodic tritium release data, however, it is likely that a tritium source term for years before 1967 could have been bounded. This type of analysis would likely be undertaken in a more detailed dose reconstruction.

Small contributors - In addition to the principal radionuclides released by LANL in its airborne emissions, there are a number of other nuclides for which release data are intermittently encountered in the available records. These nuclides include ^{54}Mn, ^{194}Au, ^{227}Ac, and others. Priority indices were not calculated for these, given the intermittent nature of the data, and the fact these nuclides were not substantial in terms of airborne releases or historical LANL operations.

Beryllium – In the site-wide FEIS (USDOE, 1979), Table 4.1.2-8 contains information on explosive tests for uranium and beryllium (see Fig. 17-11 below). Using this information, the LAHDRA team computed the priority indices in Table 17-9 based on required dilution volume in liters. Note that the priority index for beryllium is five times that of uranium. Furthermore, these data are only from explosive tests, and, as discussed in Chapters 11 and 20, other sources of beryllium, such as the beryllium shop and initiator testing, existed at LANL.

TABLE 4.1.2-8

CALCULATED ATMOSPHERIC CONCENTRATIONS OF ELEMENTS USED IN DYNAMIC EXPERIMENTS[c]

Element	1976 Annual Usage (kg)	Percent Aerosolized	Annual Avg. Conc. (ng/m^3) @ 4 km	Annual Avg. Conc. (ng/m^3) @ 8 km	Applicable Standard (ng/m^3)
Uranium (D-38)	1023	10[a]	0.1	0.04	9000
Be	25.5	2[a]	0.0007	0.0002	10 (30 day avg.)
Hg	36.1	100[b]	0.05	0.02	None
Pb	18.6	100[b]	0.02	0.08	None
TOTAL			0.17	0.068	10,000 (For total heavy metals N > 21)

a)Based on experimental measurement.

b)Assumed percentage aerosolized.

c)See Appendix H, pages H-37, H-38, and H-104, for update.

Fig. 17-11. 1979 FEIS Data on Uranium and Beryllium in Dynamic Experiments

Table 17-9. Priority index calculations for depleted uranium and beryllium emissions in 1976 based on data from LANL's 1979 FEIS

Material	1976 Annual Usage (kg)	Percent Aerosolized	Aerosolized Quantity (kg)	Applicable Standard (ng/m^3)	Priority Index (L)
Depleted Uranium	1023	10%	102.3	9,000	1.14×10^{13}
Beryllium	25.5	2%	0.51	10	5.10×10^{13}

Pre-1973 LANL plutonium releases – Figs. 17-12 and 17-13 are a table and text, respectively, taken from the site-wide FEIS that documents the 1.2-Ci cumulative historical release value for airborne plutonium through 1972. The assessment of airborne plutonium releases from LANL operations would benefit from further examining airborne plutonium releases before 1948, since there were minimal control measures in place during this period.

TABLE 4.1.2-3

ATMOSPHERIC RELEASES OF RADIOACTIVITY

Cumulative Radionuclides Released to the Atmosphere Prior to 1973[a]

^{3}H	120,000
Mixed Fission Products	0.006
^{235}U	0.086
^{238}U	0.005
^{238}Pu	0.056
^{239}Pu	1.2

Fig. 17-12: Cumulative airborne radionuclide releases through 1972, as reported in the LANL FEIS

The inventory of radioactive atmospheric releases before 1973 (see Table 4.1.2-3) was made on the basis of stack sampling through December 1972.[4-42] The absence of stack sampling programs during the early years of the Laboratory and continuing uncontained tests with high explosives involving natural or depleted uranium prevented preparation of a complete inventory. In general, the inventory covers releases during the period from 1948 through 1972 for plutonium, 1961 through 1972 for mixed fission products, and 1967 through 1972 for other radionuclides such as tritium, ^{235}U, and ^{238}U. Inventories of short-lived nuclides such as ^{131}I, ^{88}Rb, ^{133}Xe, ^{135}Xe, ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O (whose half-lives range from about 2 minutes to 8 days) were not included, since they decay rapidly and have little biological significance. The activity values for ^{239}Pu include contributions from ^{241}Am and other alpha emitters associated with the ^{239}Pu. Data since 1973 is based on actual stack sampling.

Probable releases of radioactivity to the atmosphere during the next 25 years are likely to be less than releases to date. For example, if releases of plutonium were to continue at the 1976 rate for 25 years, the cumulative amount would be less than 1.5% of the total plutonium released before 1976. Construction and use of a new plutonium facility with extensive filtration equipment is expected to significantly reduce plutonium emissions. At the 1976 rate, tritium releases over 25 years would be about the same as the total before 1976. New treatment equipment and construction of new facilities for tritium research are expected to significantly reduce tritium releases from the 1976 level.

Fig. 17-13. Text regarding airborne releases before 1973 from the LANL FEIS

Alternate Methods for Characterizing Airborne Releases

Until around 1978, releases of airborne plutonium from LANL were either not measured at all, or were improperly measured or reported. Major release points for which there are no plutonium measurements include the historic D-Building, the first plutonium component manufacturing facility in the world, and DP West Site releases before 1948. D-Building operated until around 1953. Releases from other building stacks at DP Site, aside from the main Building 12 stacks, were also not included in any LANL compilations. The LANL plutonium release compilations also did not consider non-point source emissions, including those from accidents and incidents that released directly to the environment without passing through a stack with an associated monitoring system, such as major fires at plutonium disposal areas in the 1940s, or radioactive disposal area operations that continue to this day. Until around 1959, release points at LANL, such as DP West, were not provided with single stage HEPA filters (Maraman et al., 1975). A second stage of HEPA filters were finally installed around 1973. Until the mid-1950s, the DP West Site Stacks were not equipped with an appropriate sampling system. An accurate estimate of LANL plutonium releases thus cannot be made from LANL data, given its failure to measure all releases. At best, the calculated prioritization represents a lower bound of total LANL releases.

The LAHDRA project examined the feasibility of estimating the releases using two alternate methods: back calculation from soil concentration, and back calculation from plutonium levels in Los Alamos residents. The process of "back calculation" involves to taking the soil concentration (or plutonium levels in residents) and inferring what the plutonium releases must have been in order to result in the measured

concentration(s). Utilizing these back calculation methods helped the LAHDRA team identify key documents related to LANL releases, and understand the limitations associated with estimating LANL releases through these alternate methods. Future independent assessments of LANL releases will likely incorporate several back calculation methods, comparing the results of each method to available data in order to establish both a lower and upper bound for the releases.

Plutonium Soil Measurements as Indicators of Historical Releases

Efforts by LANL

Sometime around 1957, Harry Jordan and Ralph Black, employees at LANL, attempted to measure the amount of plutonium in the soil around LANL. They collected several soil samples from areas within a 1 mi radius of DP West before global fallout impacted the United States and New Mexico. The resulting plutonium concentrations thus do not reflect any contributions from global fallout, and therefore measure only concentrations resulting from LANL emissions. The results of Jordan and Black's work are presented in Figure 17-14, which is taken from their publication entitled, "Evaluation of the Air Pollution Problem Resulting from Discharge of a Radioactive Effluent" (Jordan and Black, 1958). In Figure 17-14, canyons are represented by darker areas, and circles of increasing distance from the main stacks at DP West, along with soil sampling results and locations are depicted.

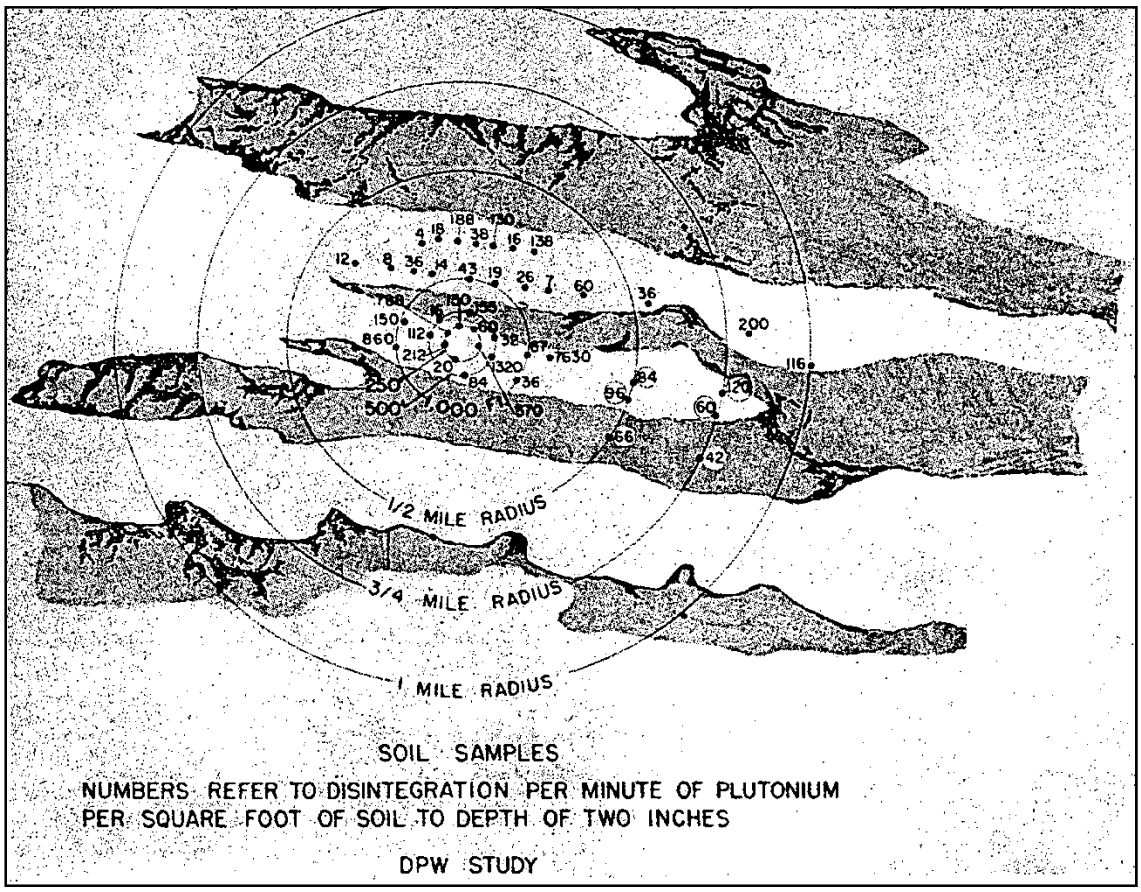


Fig. 17-14. Plutonium Soil Measurements at DP West Site, as reported by Jordan and Black (1958)

Jordan and Black asserted that they were able to compare the soil concentration values with the actual release data since releases were measured at DP West. Only the six results to the east of DP West that are circled in Figure 17-14 were recognized by Jordan and Black because they "show rather remarkable agreement" with the LANL stack effluent records indicating 13.1 g, or 0.82 Ci, of plutonium had been released over the previous nine years.

The LAHDRA team identified five major problems with the Jordan and Black analysis:

- The LAHDRA team was unable to find any supporting records or logbooks concerning the referenced work, so is unable to validate any of the data or results;

- Jordan and Black excluded any soil samples with high plutonium concentrations, for reasons that are unclear and appear to be erroneous;

- Jordan and Black compared the soil results to incorrect stack monitoring results, and asserted that the soils and stack data agreed. Corrections for sample line loss of up to a factor of five and filter burial of 2.33 were not generally made until the late 1970s (Fuehne, 2008);

- Jordan and Black analyzed too much soil at once, resulting in low and variable plutonium recovery from soil in the acid leaching process. Therefore, the reported soil concentrations were likely lower than the actual concentrations. In addition, samples to the north of the selected (circled) samples were reported to have more than twice the concentration of plutonium, and they also suffered from low plutonium recovery;

- Jordan and Black utilized a qualitative, not quantitative, laboratory method to estimate soil concentrations. The method was intended to determine whether plutonium is present, and not meant to determine how much plutonium is present (Flack et al., 2004).

The Jordan and Black soil measurements represent a lower bound of the footprint from DP West emissions. The Jordan and Black data is reported in units of dpm per square foot to a depth of 2 inches. Later environmental data is reported in concentration (pCi/g) for the same depth. Beyond conversion of the radiation units, one must have the soil density to convert soil in a square foot to grams. One can assume a soil density of 1.6, and dividing the values by 6600 will convert these measurements to the units commonly expressed today as pCi/g. The value of 200 above the six selected values would correspond to 0.03 pCi/g; however, no correction for recovery was made to those data, and the actual concentration is likely higher. In addition, no correction has been made for weathering or the loss of plutonium with time.

The Jordan and Black data can be used to estimate plutonium releases from DP West, without needing to account for background. In addition, since these data represent the earliest soil samples collected to our knowledge, the impact of weathering would be smaller than samples collected more recently.

In 1970, other LANL scientists, William Kennedy and William Purtyman, collected soil samples at 12 locations around DP West, and analyzed them for plutonium and strontium. They published this work in a report entitled, "Plutonium and Strontium in Soil near Technical Area 21"(Kennedy and Purtymun, 1971). Kennedy and Purtyman reported measured soil plutonium concentrations that were much higher than those reported by Jordan and Black. However, by attributing some concentrations to global fallout, and assuming that four times more plutonium was deposited on the soil than what Jordan and Black had estimated, Kennedy and Purtymun asserted that their results agreed with a likely understated DP West stack emission estimate of 24 g of plutonium through 1969.

Efforts by the LAHDRA Project Team: Is there a footprint?

A logical question to ask, then, is whether there is excess plutonium in the soils around LANL. Both the Jordan and Black and Kennedy and Purtyman analyses, in spite of their limitations, show a footprint around the DP Site. In addition results from these two analyses, an electronic copy of 650 plutonium

measurements resulting from soil samples collected after 1974, when the LANL laboratory methods correctly measured the plutonium in soil, was provided to the LAHDRA team. Figure 17-15 provides a plot of all of these data.

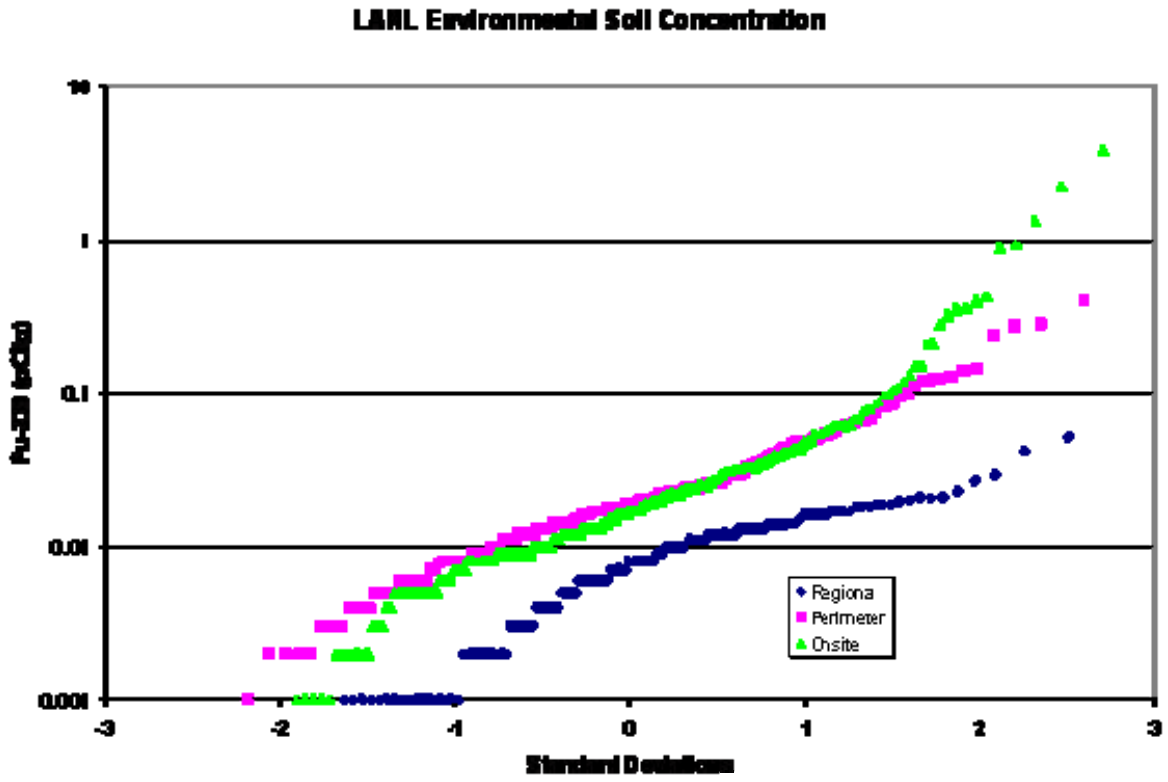


Figure 17-15: LANL Environmental Soil Concentrations.

Figure 17-15 shows regional (blue diamonds), perimeter (pink squares), and onsite (green triangles) plutonium soil data, excluding 16 data points with negative or zero results that cannot be shown on a log plot. The log plot indicates that the bulk of the data is log-normally distributed, and tail off at the lower end of the concentration range because of analytical limits of detection limits. However, when looking at the higher concentrations, the onsite and perimeter data distributions do not appear to be lognormal (as a straight line on a log plot would indicate), providing evidence of outliers.

Three of the highest four soil concentration values found in perimeter samples collected at the airport station location, which is near DP Site. Of the 21 soil concentrations greater than 0.1 pCi/g that were found in samples collected onsite, over one half came from two locations: seven were from the environmental sampling point at DP Site, and four were from East of TA-54, an area impacted by continuing releases from MDA-G. Thus, the bulk of the outliers came from known LANL releases at DP West and MDA-G. Only a few of the 650 samples show clear evidence of a footprint (decrease in plutonium concentration as distance from the source increased), primarily because the only samples that

would indicate the presence of a footprint would be those that were in the vicinity of the release points. Most of the samples were a considerable distance from DP Site, and also tended to be located upwind based on average daily weather conditions. Furthermore, the dataset does not include any environmental samples collected around D-Building, another major plutonium release point.

Weathering of soil can reduce the plutonium concentration observed in a soil sample collected decades later. In recent years, LANL staff have asserted that plutonium soil concentrations are declining to levels indistinguishable from background, noting that: "most radionuclides in LANL and PM (perimeter) areas, with the exception of ^{238}Pu in soils from PM, significantly decrease in concentration over time, so that by 1996 most radionuclides were approaching values similar to [background]" (Fresquez et al., 1998). The relatively few "footprint" data were likely impacted by weathering, and the footprint from operations in the 1940s and 1950s had the longest amount of time for weathering to impact the soil concentrations. In order to properly back calculate the LANL plutonium source term (estimated release) from soil concentrations; it will be necessary to understand the magnitude of weathering in relation to the time elapsed from plutonium release to soil measurement.

Efforts by the LAHDRA Project Team

Suggestions for Improvement of the Current Analysis

The historical LANL soil measurement data that are available and that have been used to date in attempting to back calculate the LANL plutonium releases are not ideally suited for this task. The areas around D-Building and DP West have been heavily disturbed, and finding suitable soil sampling locations there would be problematic. However, a LANL technician observed that the hillside of South Mesa across Los Alamos Canyon from the TA-1 has remained relatively undeveloped and undisturbed; as such, this area should be considered for a new soil sampling program. The samples should be collected along the canyon rim from the bridge at Diamond Drive to the area across from DP West. If possible, the samples should be analyzed with a new method of measurement called sector field inductively coupled plasma mass spectrometry (SF-ICPMS). This method can distinguish between weapons-grade plutonium (that has not been used in a nuclear weapon) and fallout plutonium (left over after a nuclear detonation). Using this method for soil analyses could cleanly separate plutonium in the soil from global fallout and soil impacted by LANL releases. This method has been successfully used at the Nevada Test Site (NTS) (Ketterer and Szechenyib, 2008). Without SF-ICPMS, the back calculation must include an estimate of plutonium attributable to global fallout in current samples and that value must be subtracted from the measured plutonium concentration in the soil sample. This subtraction increases the uncertainty in the calculation. Using a more accurately measured plutonium fraction from SF-ICPMS analysis would result in a more accurate estimate of the LANL plutonium contribution in any soil sample. Without any new soil

samples, the material found by the LAHDRA team in various LANL document repositories could be used to estimate historical LANL plutonium releases along with a rigorous effort to quantify uncertainties associated with the various parameters associated with the back calculation; however, the uncertainties would be greatly reduced if a new program of measurements, including those analyzed via SF-ICPMS, was undertaken.

Analysis of Measurements of Plutonium in Body Tissues of Los Alamos Area Residents

As described previously, there is considerable uncertainty associated with LANL plutonium releases that occurred prior to 1970, especially during the early years when off-site releases were likely the highest. To address these data gaps, the LAHDRA team investigated the possibility of estimating plutonium releases by using data obtained from autopsies of LANL residents that examined the plutonium concentrations in certain types of tissues.

The LANL Human Tissue Sampling Program

The Human Tissue Analysis Program was a 35-year effort by LANL to study the levels of plutonium in workers and in the general United States population. Compilations of the LANL human tissue analysis data have been published periodically, and an overview of the program was provided in the November 23, 1995 issue of Los Alamos Science, as part of a larger summary of the Human Radiation Experiments (McInroy, 1995). Researchers at LANL began to collect tissue spontaneously in 1958 following the death of Cecil Kelley, a plutonium worker, during a criticality accident (McInroy, 1995). His autopsy indicated that although the total body plutonium burden was similar to biokinetic model predictions used at the time, the distribution across organs was significantly different than expected. This observation led to the establishment of the tissue analysis program, which included tissues collected from deceased LANL employees known to be occupationally exposed. Members of the general public were also included as controls. In later years, the number of non-occupationally exposed individuals in the tissue program increased substantially in response to growing concern regarding worldwide fallout due to nuclear weapons testing. These tissues were collected with the specific goal of determining the "background" level of internally deposited plutonium due to atmospheric fallout. Nearly 1,000 decedents had tissues removed during autopsies and sent to LANL by coroners. The logbooks from the human tissue sample program and archived solutions of many of the sampled tissues were transferred by LANL to the United States Transuranium and Uranium Registries (USTUR) after the program ended. USTUR maintains them still today.

The LAHDRA project team considers the human tissue data collected from Los Alamos area residents important because they may be able to help characterize their exposures resulting from LANL plutonium releases during the initial decades of the facility's operations. Early samples typically included lung, tracheobronchial lymph nodes, liver, kidney and bone specimens (together, these organs contain about 90 percent of plutonium that is retained in the body); in later years, the gonads, thyroid, and spleen were also sampled (McInroy, 1995). The LAHDRA project team is primarily interested in results from the liver, skeleton, and lungs because the lungs provide information about plutonium inhaled in the last few years prior to death, while plutonium in the liver and skeleton provides an estimate of the total plutonium inhaled over a person's life. By comparing the ratios of plutonium concentrations in these types of tissues, it is possible to determine whether observe differences between people who were exposed to plutonium long ago and people who had more recent exposures.

Data from the Los Alamos Tissue Program were published in units of disintegrations per minute per kg (dpm kg^{-1}) of organ. There are models that can predict how plutonium will move throughout the human body. For example, International Commission of Radiological Protection (ICRP) Report No. 30 has published limits for intakes of radionuclides by workers, which are established for each organ based on dosimetric models for inhaled radionuclides such as plutonium. The ICRP has also developed "reference" male and females based on data on mass of the various organs of the body, chemical composition of the body and various tissues and physiological data. During the late 1970s, when the autopsy data were published, the hypothetical "Reference Man" was between 20-30 years of age, weighing 70 kg, is 170 cm in height. This model was used to generate the dpm kg^{-1} values published for the Los Alamos Tissue Program. The LAHDRA team recognizes that more updated values are available for women and children, and any future efforts to use these data in a dose reconstruction would incorporate these values.

Based on the model presented in ICRP No. 30 (ICRP, 1979), plutonium is distributed with 45% going to the liver, 45% to bone, a small fraction to other organs, and the remainder largely excreted. In order to relate the measured data to potential dose, a dose coefficient in Sv per dpm kg^{-1} skeleton can be derived as follows: a systemic uptake of 1 dpm ultimately results in 0.45 dpm in the skeleton or liver. The liver has a mass of 1.8 kg in Reference Man, resulting in 0.25 dpm kg^{-1} in liver tissue for each dpm that is incorporated into the body. For skeletal samples, a conversion is needed depending on the type of bone that was sampled. Plutonium is concentrated in the trabecular bone rather than in hard, compact cortical bone. Trabecular bone is the dense, semirigid, porous, calcified connective tissue forming the major portion of the skeleton of most vertebrates. Reference Man (ICRP, 1975) notes that thoracic vertebrae, the spongy bone in which marrow resides, are about 75% trabecular. The entire skeleton ranges from 10% to 20% trabecular bone by weight. If the tissue sample had the same proportions, dividing by about two kg (or 20% of the 10 kg total mass of skeleton) would yield a value of 0.225 dpm kg^{-1} skeleton. This

value is close to that for liver. The dose resulting from a one dpm systemic uptake depends on the chemical form of the intake (and, of course, on the isotope, particle size, etc.). For inhalation of ^{239}Pu oxide, USEPA's Federal Guidance Report No. 11 asserts a dose equivalent factor of 8.21×10^{-04} Sv Bq^{-1} for bone surfaces, which converts to 1.37 mrem dpm^{-1} (intake) (USEPA, 1988). Dividing by 1.37 mrem by 0.225 dpm kg^{-1} skeleton then gives six mrem committed bone dose per dpm kg^{-1} skeleton.

The committed effective dose equivalent (CEDE) is a measure of radiation exposure that estimates risk by adding the dose from all of the organs (weighted for their risk for cancer) for as long as the radioactive material will be present in the body. On the basis of CEDE, the value for ^{239}Pu oxide is 0.6 mrem per dpm kg^{-1} skeleton, or 0.6 mrem per dpm kg^{-1} liver. For more soluble forms (inhalation Class W), the values for ^{239}Pu are 16 and 0.9 mrem per dpm kg^{-1} skeleton for bone surfaces and CEDE, respectively. Values for ^{238}Pu are similar to those for ^{239}Pu. A simplification expressing the results in the right "ballpark" would be that one dpm kg^{-1} results in approximately one mrem CEDE for either the liver or vertebrae results from the autopsy program.

Understanding Worldwide Fallout and Comparison of Results in Various Parts of the Country

In the past, when LANL reported results from the human tissue program, comparisons were made between various areas of the country. Samples from New York City were taken during 1967-1968, while samples from all other areas of the country (other than near Los Alamos) were taken only during 1974 - 1975. By that time, LANL's plutonium releases had been greatly reduced by installing HEPA filters on the various exhaust points. Consequently, worldwide fallout from weapons testing became an increasingly important source of plutonium exposure for Los Alamos residents. Individuals who arrived in Los Alamos after the 1960s most likely experienced intakes of nuclear fallout from weapons testing, while people who arrived earlier could have inhaled or ingested greater amounts of plutonium due to LANL releases.

The comparisons LANL staff published have considered only the LANL data for individuals who died in those limited years (1974-75 or 1967-68) in order to support comparison with the datasets collected from other parts of the country, since cases from New Mexico for earlier years would have been exposed to different levels of nuclear weapons testing fallout. Since there are only a few cases for those years, data from early and late arrivals, men and women, old and young, etc., were combined. When the combined case data from these few years are compared to other areas of the country, the variability is so great that it is impossible to tell if there was a difference between Los Alamos and other areas or not. Based on this result, LANL has asserted that there are no measureable differences between plutonium tissue concentrations in Los Alamos and other areas of the country. While this statement is technically correct, the LAHDRA team believes that it is misleading.

LANL has analyzed the data to demonstrate that the differences in median values of plutonium concentration in tissues between states in the U.S. were small. However, the autopsy results from deaths at the Los Alamos Medical Center (designated as either Los Alamos residents or residents of Northern New Mexico) were generally the highest median values for nearly all organs compared to other states.

A similar comparison was provided by McInroy et al. in 1979 in the journal *Health Physics*, wherein the cumulative frequency distributions of liver plutonium concentrations (dpm kg^{-1} liver) among residents of Los Alamos and Denver were compared; they were reported to be nearly identical. However, the vertebrae autopsy samples from Los Alamos are higher than Denver, and their different slope indicates that the plutonium has been in the body longer. These data are shown in Fig 10-16 and Fig 10-17. To facilitate comparison, the figures from McInroy et al. were superimposed on one another in those figures.

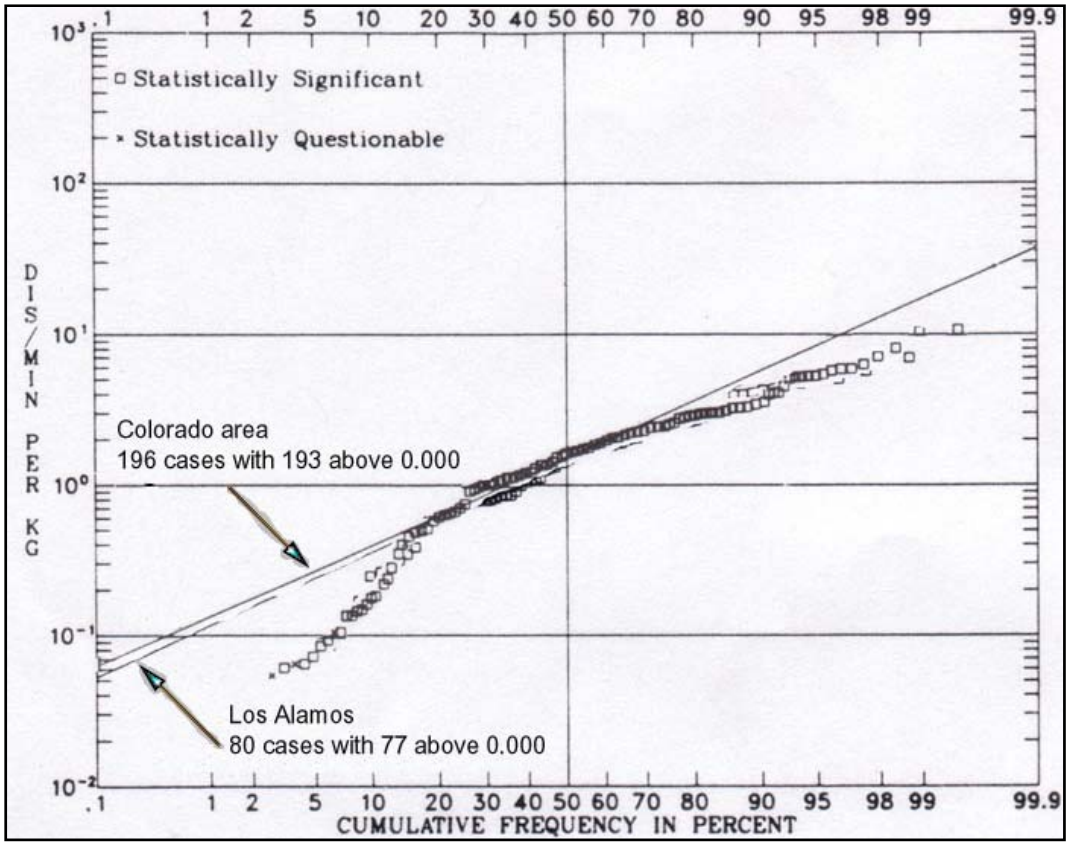


Fig. 17-16: Liver Autopsy Results

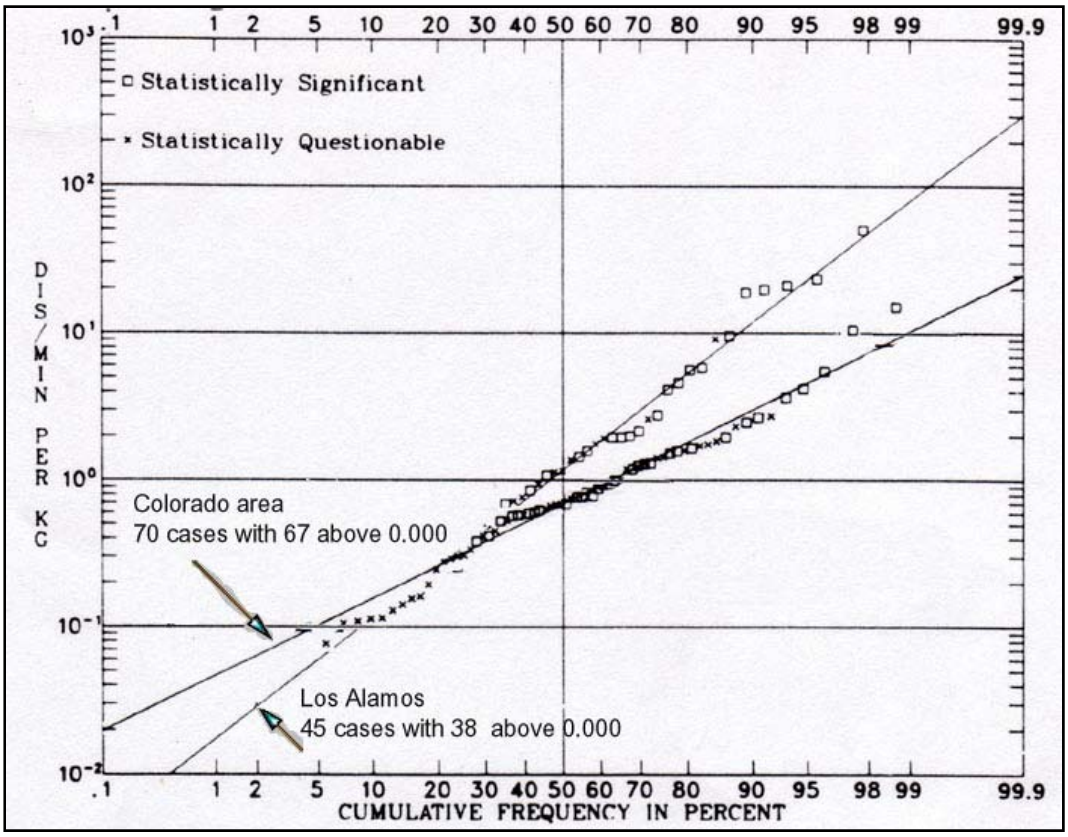


Fig. 17-17: Vertebrae Autopsy Results

It is curious that the liver data for Los Alamos and Denver show identical results, since most of the Los Alamos cases used in that figure were obtained in the 1960s**,** while all of the tissues for cases from Denver were obtained in the 1970s. If fallout levels were identical, the Los Alamos liver results would have been expected to follow a curve that was below that of Denver, not identical to Denver, since the contribution of fallout to total dose would be expected to be greater in the 1970s. The fact that the curves seem similar despite the difference in dates suggests that either the fallout levels in Los Alamos were higher than Denver, or that the Los Alamos cases had added plutonium exposure prior to the 1970s. The vertebrae results show differences between Los Alamos and Denver, with the differences occurring in the population with higher bone concentrations. This result also appears to be consistent with the hypothesis that releases from LANL impacted the greater Los Alamos population.

If there were two distinct populations in Los Alamos (long term residents with plutonium both from the site releases and global fallout, and short term residents with primarily global fallout in their tissues), a bend" in the curve indicating added plutonium in the fraction of the population living nearest to the release points would be expected. However, no such bend is seen, which is likely due to the fact that if

the added plutonium resulted from facility operations, its impact would be uneven in the population, with only a few individuals impacted based on proximity to the release points, the winds, and other factors. It is likely, then, that releases from the site were not sufficient to cause this bend in the cumulative frequency distribution (CFD) plot, or that the inherent variability of various factors dominates the distribution, thus masking the presence of two populations.

The LAHDRA team conducted a supplemental analysis where the ratios of vertebrae to liver concentrations were evaluated. As noted previously, the older ICRP model for plutonium behavior in the human body (that was used by McInroy) assumes that the skeleton retains plutonium with a biological half-life of 50 years, and that the liver retains plutonium for 20 years (McInroy et al., 1979). Therefore, a larger vertebrae to liver ratio indicates an earlier exposure. Fig. 17-18 shows a CFD plot for the ratio of vertebrae to liver results for all autopsy cases that had data for both organs. Two of the data sets shown in Fig. 17-18 (Denver and Los Alamos) were used to generate a line of best fit, based on an exponential distribution (the other two datasets in this figure are discussed in the next section). Based on a visual comparison, it appears that the Los Alamos vertebrae to liver ratios are, in general, higher than those for Denver. The results from Denver appear to be lognormally distributed, with a median ratio of 1.73. One individual (out of 38) had nearly 25 times as much plutonium in his vertebrae as in his liver. For the Los Alamos data, the median vertebrae to liver ratio was 2.72. Three of the 17 ratios are greater than 25, with one result approaching a ratio of 200 (off scale, and not shown in Fig.17-18). Taken together, the data indicate that exposures occurred earlier in Los Alamos than in Denver and are therefore likely to be related to off-site releases. It is important to note that the Denver population was *not* significantly exposed to plant releases from Rocky Flats. The downwind direction from Rocky Flats is predominately toward the east, and, although there are people living in this area, the population density is very low, and the likelihood that these residents were included in the Denver study is very low.

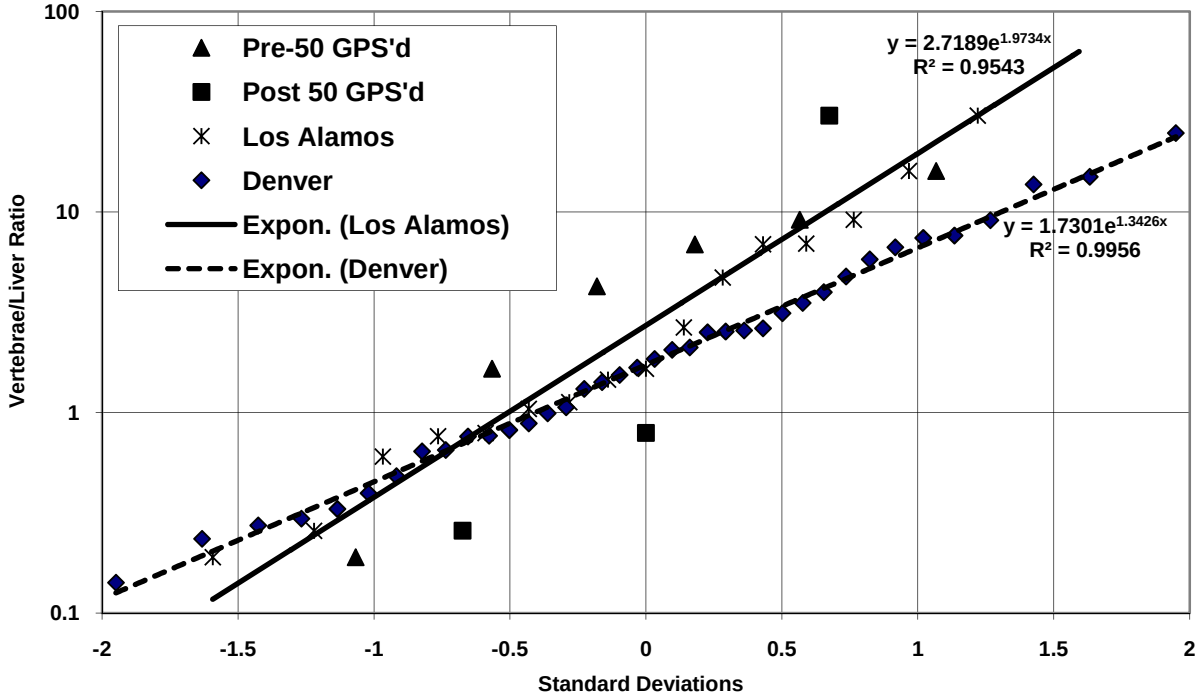


Fig. 17-18. Cumulative Frequency Distribution of Vertebrae-to-Liver Ratios

Supplemental Analysis of the Autopsy Program Results Using Residential Histories

The LAHDRA team attempted to independently analyze the autopsy program results and incorporate the proximity of the autopsy cases to known sources of plutonium releases at LANL (Shonka, 2004). To accomplish this, the LAHDRA team developed residential histories for autopsy cases by cross referencing death certificates for participants in the Los Alamos Tissue Program (LANL, 1978) with yearly telephone directory listings maintained by the Los Alamos Historical Society, as well as from other LANL documents and public records. These resources were then used to determine the length of stay for each autopsy case at each address within Los Alamos, as well as the distance and bearing of each location from DP West or D-Building (if the case lived in Los Alamos during the early years when D-Building was operational).

An initial challenge for the LAHDRA team was the fact that the publicly released autopsy results were published as blind samples; the results included no information concerning identity or residential history for each case. In a small city like Los Alamos, however, relatively few deaths occurred each year. The LANL autopsy data included five attributes that could be used to establish the identity of the donor without obtaining the data from official or private records: (1) year of death, (2) resident of the city of Los Alamos, (3) sex, (4) age, and (5) cause of death. Initially, these five attributes were used to match a number of the autopsy cases to Los Alamos area residents.

In 2006, however, the death certificates and an index key for participants in the autopsy program were found by the LAHDRA team in the LANL archives (LANL, 1978). The death certificates were used to create residence histories for each autopsy case and to confirm that the methodology described above had correctly identified the cases. The death certificates also included information regarding the "usual residence" of the decedent, as well as the "length of stay" in the place of death. In instances where the individual died in Los Alamos and was also a resident of Los Alamos, the "length of stay" reported on the death certificate was considered to be the length of time that the person lived in Los Alamos.

For each participant who reportedly lived in Los Alamos, historical telephone directories were consulted for the years that the decedent was assumed to be a resident. Directories were available for the years 1943-1944 and 1946-1969; none were available for 1945. Addresses were listed as street addresses beginning in 1948. In the 1943, 1944, 1946, and 1947 directories, addresses were listed as "T-numbers;" each house in town was assigned a unique T-number. Historical maps of the original Technical Area were used to identify the exact location (latitude/longitude) of the T-number addresses. Several other sources were also consulted, including a September, 1956 AEC Albuquerque Operations Office directory, AEC Los Alamos directories for 1966-1972, a 1968-1969 Los Alamos school directory, and a 1964 Albuquerque Operations phone book.

For each name listed in the human tissue program information database, the "year of arrival in Los Alamos" and the "length of time in Los Alamos" variables were used to determine in which directories each participant would likely be listed. In instances in which the database contained two estimates of the "length of time in Los Alamos," the estimate corresponding to the greatest number of years was used in the search. For each year that it was believed that the participant lived in Los Alamos, the corresponding phone directory was consulted to find his or her address for that year. In many cases, participants lived at a given address for more than one year, and so the variables "begin year" and "end year" were associated with each address. The two to three years preceding and following the time period during which the participant was believed to have lived in Los Alamos were also checked in the telephone directories.

For participants who could not be located using the historical telephone directories, several other approaches were available. Obituaries printed in the *Los Alamos Monitor*, which was published several times per week, often provided detailed information regarding how long an individual lived in Los Alamos, and, in some cases, approximately where they lived. If address information was not directly provided, residential histories could be determined by searching under family members' names during the relevant time periods. Ninety names were searched using this method, and 36 matches were found. Marriage licenses often contained an address at the time of the marriage, and they were also used to confirm familial relationships between some of the participants (such as father/daughter versus spouse). In some instances (particularly for women), the residential history could easily be tracked in the phone

directories using a spouse's name. The LAHDRA team searched for one hundred and two marriage licenses using this method, and found and nine matches. Finally, the LAHDRA team used online genealogy services as an additional source of information.

In total, there were 236 autopsy cases for which tissue activity data were available; 60 of those participants were LANL employees. These participants were associated were 809 residential locations, of which 677 were identified as addresses, and 542 were geocoded using an Internet-based service (Tele Atlas®) in order to calculate their distance to D-Building and DP West. For some addresses, a global positioning satellite (GPS) unit was used to determine coordinates. In some cases, the historical address had been re-developed, and was no longer a residence. For each address, the LAHDRA team calculated its distance from D-Building and DP West.

To date, the LAHDRA team has conducted very limited analyses using the residential information from the autopsy cases. This work was done around 2004, prior to the discovery of the complete list of case names and the development of the detailed residential histories based on the death certificates. The vertebrae to liver ratios amongst individuals who lived in Los Alamos prior to or after 1950 were compared (Fig. 17-20). At the time of this analysis, only a handful of samples had residential information in addition to liver and vertebrae results. For example, there were only three cases for post-1950, one of which is an outlier. The pre-1950 data had a greater median value and slightly smaller geometric standard deviation compared to the full dataset for Los Alamos. The median estimated exposure, based on the ratios, is higher among long-term residents, by a factor of five.

The development of a more comprehensive list of cases (and their residential histories) by the LAHDRA has created a dataset that could be used in future dose reconstruction efforts to reduce uncertainty, and possibly permit using the autopsy data for providing upper and lower bound estimates for LANL releases. A full analysis of the data would require that the distance and bearing from significant release points at Los Alamos, along with the time dependent source term, be incorporated into a mathematical model. Additionally, the date of death should be used in correcting the autopsy results for fallout.

Additional Avenues for Investigation

There are significant challenges to using the autopsy data to establish an upper or lower bound for LANL releases. In order to interpret the autopsy results, a timeline of exposures to both fallout and site releases would be needed. One of the challenges in establishing bounding estimates will be determining the levels of fallout present in the individual. Researchers would need a means of separating the observed plutonium levels due to LANL operations and those due to global fallout. The uncertainties in the many factors needed to perform this calculation may result in undesirably large uncertainties in the final answer.

The development of a new method of measurement, however, may be able to address this question. This method is called Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and it can distinguish between weapons-grade plutonium that has not been used in a nuclear weapon and plutonium from fallout resulting from a nuclear detonation.

Archived solutions of the original samples taken under the Los Alamos human tissue program, as well as associated logbooks, have been maintained by USTUR for many of the autopsy cases. As a result, it may be possible to determine how much of any autopsied individual's exposure was due to fallout or LANL releases by reanalyzing archived tissues using ICP-MS. USTUR has performed an initial study of this method with promising results. Using ICP-MS for the autopsy cases would not just re-analyze the samples and assert a new and perhaps more accurate measurement of plutonium in a given sample, but would also cleanly separate out the plutonium levels due to global fallout from LANL operational releases using a highly accurate measurement of the various plutonium nuclei. A simple $^{239/240}$Pu fraction could be applied to McInroy's data. Global fallout has a characteristic ratio signature of ^{240}Pu to ^{239}Pu of 0.18, whereas weapons grade plutonium not expended in a nuclear bomb has a much lower atom ratio of 0.04. ICP-MS easily separates these two atoms by mass, while traditional measurements employing alpha spectrometry cannot, since the alpha energies for 240Pu (5.255 MeV) and ^{239}Pu (5.244 MeV) are too close to be resolved. Work at the NTS found that atom ratios for 240Pu/239Pu in soil exhibit a simple two-component mixing of plutonium ratios from nuclear testing at NTS and global fallout (Cizdziel et al., 2008).

LAHDRA team members and USTUR personnel have shared information concerning the autopsy results. A complete 1991 computer printout from the program has been obtained that can be reviewed against the publications that document the autopsy results. This printout contains information protected under the Privacy Act, and it cannot be released to the public. Attempts are underway to "clean up" the old computer output so that it can be scanned and optical-character-recognition processed so it can be entered into a spreadsheet to facilitate analysis. If that task is successful, the data from previous publications used by LAHDRA (from the 1980 time frame) will hopefully be reconciled with the LANL data.

Lastly, the LAHDRA team examined other autopsy cases from New Mexico in an effort to review the possible plutonium exposure from the July 16, 1945 Trinity test. That review found no cases in the highest exposure contours of the downwind plume area as delineated in Quinn (1990). The highest recorded plutonium levels were found in a woman from Truchas, New Mexico, who was alive during the Trinity test. The plutonium concentration in her liver was 60 times higher than that of the average New Mexico resident. Truchas is next to the one mR h^{-1} contour line (at H+12 hours), which does not reflect internal doses received from inhalation or ingestion of radioactive material (Quinn, 1990).

Prioritization of Waterborne Radionuclide Releases

Since 1944, LANL operations have produced liquid wastes containing radioactive materials. Waterborne radioactive waste was released without treatment to Acid Canyon (see Fig. 17-19) from 1944 until 1951, when the TA-45 treatment plant became operational.

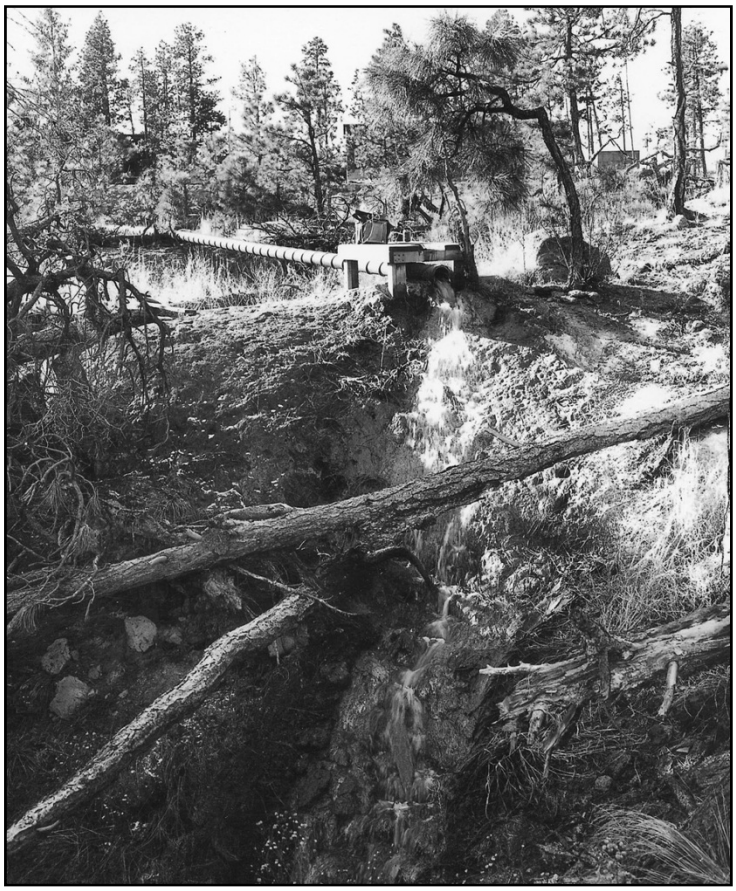


Fig. 17-19. During early LANL operations, untreated liquid radioactive wastes were discharged to Acid Canyon through this pipe.

Prioritization has been accomplished for waterborne releases of total plutonium, ^{89}Sr, ^{90}Sr, and tritium. These radionuclides are the only ones for which more-or-less complete historical compilations of liquid releases prepared by LANL were found. LANL also reported waterborne releases for the following radionuclides at various times over the years: ^{227}Ac, ^{241}Am, ^{140}Ba/^{140}La (radioactive lanthanum), ^{7}Be, ^{134}Cs, ^{137}Cs, ^{57}Co, ^{60}Co, gross alpha, gross beta, ^{54}Mn, ^{22}Na, ^{83}Rb, ^{84}Rb, ^{75}Se, ^{85}Sr, total uranium, ^{234}U, and ^{88}Y. Release data for these nuclides were either only provided for brief time intervals, or were redundant with the longer-term historical compilations. Prioritization of these nuclides was therefore not attempted in this initial assessment. However, it is expected that Priority Indices for these nuclides, if calculated, would not differ substantially from those determined for the primary nuclides of interest (i.e., plutonium, ^{89}Sr, ^{90}Sr, and tritium).

As for the airborne release data, LANL's waterborne releases have been prioritized by calculating a Priority Index for each nuclide of interest for each year. The Priority Index is defined as the volume of water required to dilute the reported (or estimated) quantity released down to the maximum concentration allowed for a release to the environment. Table 17-10 shows the maximum allowable waterborne concentration values used in the Priority Index calculations. These values were taken from 10 CFR 20 Appendix B, Table 2, Column 2 (USNRC, 2010). The maximum allowable concentrations for ^{238}Pu, ^{239}Pu, and ^{240}Pu are all 2×10^{-8} μCi per milliliter, so this value was used to calculate the Priority Index for total plutonium releases.

Table 17-10. Maximum Effluent Concentrations Used for Waterborne Radionuclide Prioritization

Nuclide	Maximum Effluent Concentration (μCi mL^{-1})
Total plutonium	2×10^{-8}
^{89}Sr	8×10^{-6}
^{90}Sr	5×10^{-7}
Tritium	1×10^{-3}

It is worth noting again that the Priority Index does not account for specific pathways of exposure or distances to offsite receptors. It is a simple tool used to evaluate the relative rank of releases of a particular radionuclide against the others.

Data Sources

The LAHDRA team used three data sources for waterborne radioactive effluents released from LANL:

- (Christenson, 1973) – A compilation of estimates and measurements of waterborne radionuclide releases to canyons and absorption beds at LANL for the period 1945 - 1972. This reference was the source of all waterborne release data for the era prior to publication of the formal environmental surveillance reports.
- LANL Environmental Surveillance Reports from 1971-1996. These contain effluent information for TA-21, TA-50 and TA-53 waste treatment plants. They are the source of the waterborne radionuclide release data for 1973 and for 1977 forward.

Waterborne discharge summary reports for 1974, 1975, and 1976. The environmental surveillance reports for 1974, 1975, and 1976 did not include waterborne release data. This information was therefore obtained from other references retrieved by the LAHDRA team (USAEC, 1975, LASL, 1976a, 1977b).

Prior to 1973, LANL reported waterborne radionuclide releases on a site-wide basis rather than attributing releases to specific release points. The reported releases for this era are a combination of measurements and best estimates. From 1973 forward, LANL generally included waterborne radionuclide releases in its annual environmental surveillance reports. However, there were cases where waterborne release data were not included in the surveillance reports, and other references had to be used. No data for waterborne tritium releases in 1975 were located.

LANL only reported total plutonium for 1945 through 1972 and for 1992. Pu-238 and Pu-239 were reported separately for 1973 through 1996, with the exception of 1992. Since the maximum allowable waterborne concentration values for Pu-238 and Pu-239 are the same, the Pu-238 and Pu-239 releases were summed for the years in which they were reported separately, thus allowing prioritization of the waterborne plutonium releases to be presented in a continuous fashion over the period 1945 – 1996.

89Sr and Sr-90 are reported separately for most years. Exceptions are 1990 through 1993 for Sr-89, and 1990 through 1992 for Sr-90. The maximum allowable concentration values for Sr-89 and Sr-90 differ by a factor of 16, so treating radiostrontium releases on a total (rather than nuclide-specific) basis was undesirable. The later total strontium releases reported by LANL potentially include strontium isotopes other than Sr-89 and Sr-90, so Sr-89 or Sr-90 releases cannot necessarily be derived from knowing the total released.

Summary of Results for Prioritization of Waterborne Releases

The prioritization data for waterborne releases of total plutonium, ^{89}Sr, ^{90}Sr, and tritium are shown in Table 17-11. The table shows the quantity released (in μCi) and the corresponding Priority Index (in liters) for each calendar year for1945 through 1996. Prioritization was not carried beyond 1996, since this year was far enough into the modern era, and prioritization primarily focused on earlier eras before treatment and monitoring capabilities had developed. Figure 17-14 is a plot of the Priority Index values for the four nuclides of interest. The periods of flat lines show where LANL has estimated annual releases, and thus do not vary from year to year. Gaps in the plots are years in which release data have not yet been located. These are seen for tritium for 1975, for ^{89}Sr for 1990 through 1993, and for ^{90}Sr for 1990 through 1992.

Plutonium: Sources of waterborne plutonium releases from LANL include DP Site (TA-21) and the central liquid waste treatment facility at TA-50. The Priority Indices for waterborne plutonium releases range in magnitude from 10^7 to 10^9. Plutonium was the highest priority waterborne release over the entire time period considered, with the exception of 1956, when radiostrontium releases from TA-35 increased significantly. These releases were from the liquid waste handling system for the RaLa laboratories located there.

Radiostrontium (^{89}Sr and ^{90}Sr): Sources of waterborne radiostrontium releases from LANL include DP Site (TA-21) and the central liquid waste treatment facility at TA-50. The Priority Indices for waterborne releases of ^{90}Sr range from 10^5 to 10^8. For ^{89}Sr they range from 10^4 to 10^8. ^{90}Sr ranks the second highest priority behind plutonium for 1945 through 1972; it was the highest priority for 1956, due to an accidental release from the TA-35 waste tanks. ^{89}Sr likewise ranks higher than plutonium for that year for the same reason. After 1972, ^{90}Sr releases prioritizes similar to waterborne tritium releases until 1983. Relatively speaking, waterborne ^{89}Sr releases only appear important for the few years following the 1956 release from the TA-35 tank farm, and perhaps for the 1983 – 1984 and 1987 – 1988 periods.

Tritium: Waterborne tritium was released from DP-Site (TA-21), the central liquid waste treatment facility at TA-50, and the research facilities at TA-53. The prioritization for waterborne tritium releases prior to 1971 reflect an estimate made by LANL given the lack of monitoring data. LANL estimated that

5 Ci per year were released for the period 1945 through 1970 (Christenson, 1973). Figure 17-14 therefore shows a flat line for the tritium Priority Index for this period. There is also a gap in the tritium curve for the year 1975, as, thus far, no release estimate for this period has been identified. Tritium appears to rank as a relatively low priority until the early 1970s. As of 1984, it ranked as the second-highest priority waterborne radionuclide release behind plutonium. The Priority Indices for waterborne tritium releases range from 10^5 to 10^8.

Conclusions regarding prioritization of waterborne radionuclides

The current results indicate that in regards to waterborne releases, plutonium is of most concern. It is not yet possible, however, to definitively address the relative importance of waterborne effluents versus airborne effluents. We can note, though, that, in general, pathways for public exposure from liquid releases appear to have not been as complete as those for airborne releases, due to the ephemeral nature of surface water flow in many cases, with a large part of off-site transport possibly occurring during heavy rains or runoff from periods of snow melting.

Table 17-11. Waterborne Release Estimates and Priority Indices [a]

Year	Total Plutonium		^{89}Sr		^{90}Sr		Tritium	
	Release (µCi)	Priority Index (L)	Release (µCi)	Priority Index (L)	Release (µCi)	Priority Index (L)	Release (µCi)	Priority Index (L)
1945	2.38E+04	1.19E+09	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1946	2.38E+04	1.19E+09	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1947	2.38E+04	1.19E+09	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1948	2.38E+04	1.19E+09	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1949	2.38E+04	1.19E+09	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1950	2.38E+04	1.19E+09	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1951	1.31E+03	6.55E+07	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1952	1.42E+03	7.10E+07	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1953	2.24E+03	1.12E+08	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1954	3.21E+03	1.61E+08	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1955	3.14E+03	1.57E+08	4.00E+04	5.00E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1956	1.81E+03	9.05E+07	9.35E+05	1.17E+08	1.65E+05	3.30E+08	5.00E+06	5.00E+06
1957	1.94E+03	9.70E+07	2.13E+05	2.66E+07	3.70E+04	7.40E+07	5.00E+06	5.00E+06
1958	1.47E+03	7.35E+07	1.02E+05	1.28E+07	1.80E+04	3.60E+07	5.00E+06	5.00E+06
1959	2.06E+03	1.03E+08	2.60E+04	3.25E+06	4.00E+03	8.00E+06	5.00E+06	5.00E+06
1960	4.36E+03	2.18E+08	3.40E+04	4.25E+06	6.00E+03	1.20E+07	5.00E+06	5.00E+06
1961	1.07E+04	5.35E+08	9.00E+03	1.13E+06	1.00E+03	2.00E+06	5.00E+06	5.00E+06
1962	6.84E+03	3.42E+08	9.00E+03	1.13E+06	1.00E+03	2.00E+06	5.00E+06	5.00E+06
1963	6.81E+03	3.41E+08	4.50E+04	5.63E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1964	3.11E+03	1.56E+08	4.50E+04	5.63E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1965	4.48E+03	2.24E+08	4.50E+04	5.63E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1966	2.50E+03	1.25E+08	4.50E+04	5.63E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1967	6.50E+03	3.25E+08	5.80E+04	7.25E+06	1.50E+04	3.00E+07	5.00E+06	5.00E+06
1968	4.20E+03	2.10E+08	3.30E+04	4.13E+06	8.00E+03	1.60E+07	5.00E+06	5.00E+06
1969	8.36E+03	4.18E+08	5.50E+04	6.88E+06	1.30E+04	2.60E+07	5.00E+06	5.00E+06
1970	6.47E+03	3.24E+08	1.50E+04	1.88E+06	2.20E+04	4.40E+07	5.00E+06	5.00E+06
1971	7.62E+03	3.81E+08	1.30E+04	1.63E+06	3.20E+04	6.40E+07	3.02E+06	3.02E+06
1972	1.70E+04	8.51E+08	4.00E+03	5.00E+05	7.00E+03	1.40E+07	9.62E+06	9.62E+06
1973	9.40E+03	4.70E+08	4.90E+03	6.13E+05	7.50E+03	1.50E+07	1.90E+07	1.90E+07
1974	1.20E+04	6.00E+08	2.87E+03	3.59E+05	1.63E+04	3.27E+07	4.70E+06	4.70E+06
1975	1.64E+04	8.21E+08	1.77E+03	2.21E+05	6.07E+03	1.21E+07	No data	--
1976	8.92E+03	4.46E+08	9.70E+02	1.21E+05	4.62E+03	9.25E+06	1.88E+08	1.88E+08
1977	4.18E+03	2.09E+08	2.29E+03	2.86E+05	3.10E+04	6.19E+07	3.97E+07	3.97E+07
1978	6.42E+03	3.21E+08	2.67E+03	3.33E+05	1.05E+04	2.10E+07	1.41E+07	1.41E+07
1979	2.40E+03	1.20E+08	6.10E+03	7.63E+05	1.42E+04	2.85E+07	3.31E+07	3.31E+07
1980	9.55E+03	4.77E+08	4.10E+04	5.12E+06	1.81E+04	3.62E+07	4.50E+07	4.50E+07
1981	5.88E+04	2.94E+09	4.16E+04	5.20E+06	2.37E+04	4.73E+07	1.74E+07	1.74E+07
1982	1.99E+04	9.96E+08	1.18E+04	1.48E+06	1.34E+04	2.68E+07	1.53E+07	1.53E+07
1983	5.33E+04	2.67E+09	5.68E+04	7.10E+06	2.54E+03	5.08E+06	1.04E+07	1.04E+07
1984	1.44E+04	7.21E+08	2.62E+05	3.28E+07	7.03E+03	1.41E+07	4.69E+07	4.69E+07
1985	9.75E+03	4.87E+08	9.01E+03	1.13E+06	1.26E+03	2.51E+06	7.69E+07	7.69E+07
1986	5.10E+03	2.55E+08	9.20E+03	1.15E+06	6.90E+02	1.38E+06	2.45E+07	2.45E+07
1987	4.60E+03	2.30E+08	6.40E+04	8.00E+06	1.00E+03	2.00E+06	1.11E+08	1.11E+08
1988	4.30E+03	2.15E+08	8.10E+04	1.01E+07	2.00E+02	4.00E+05	2.62E+07	2.62E+07
1989	2.60E+03	1.30E+08	1.80E+04	2.25E+06	1.10E+03	2.20E+06	4.10E+07	4.10E+07
1990	8.00E+02	4.00E+07	No data	--	No data	--	1.20E+07	1.20E+07
1991	1.30E+03	6.50E+07	No data	--	No data	--	1.06E+07	1.06E+07
1992	7.00E+02	3.50E+07	No data	--	No data	--	1.06E+07	1.06E+07
1993	1.10E+03	5.50E+07	No data	--	3.40E+03	6.80E+06	2.66E+06	2.66E+06
1994	3.20E+03	1.60E+08	2.00E+03	2.50E+05	3.00E+02	6.00E+05	2.23E+06	2.23E+06
1995	4.00E+03	2.00E+08	1.00E+02	1.25E+04	6.00E+02	1.20E+06	7.31E+05	7.31E+05
1996	2.64E+03	1.32E+08	6.60E+02	8.25E+04	6.00E+02	1.20E+06	1.02E+06	1.02E+06

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

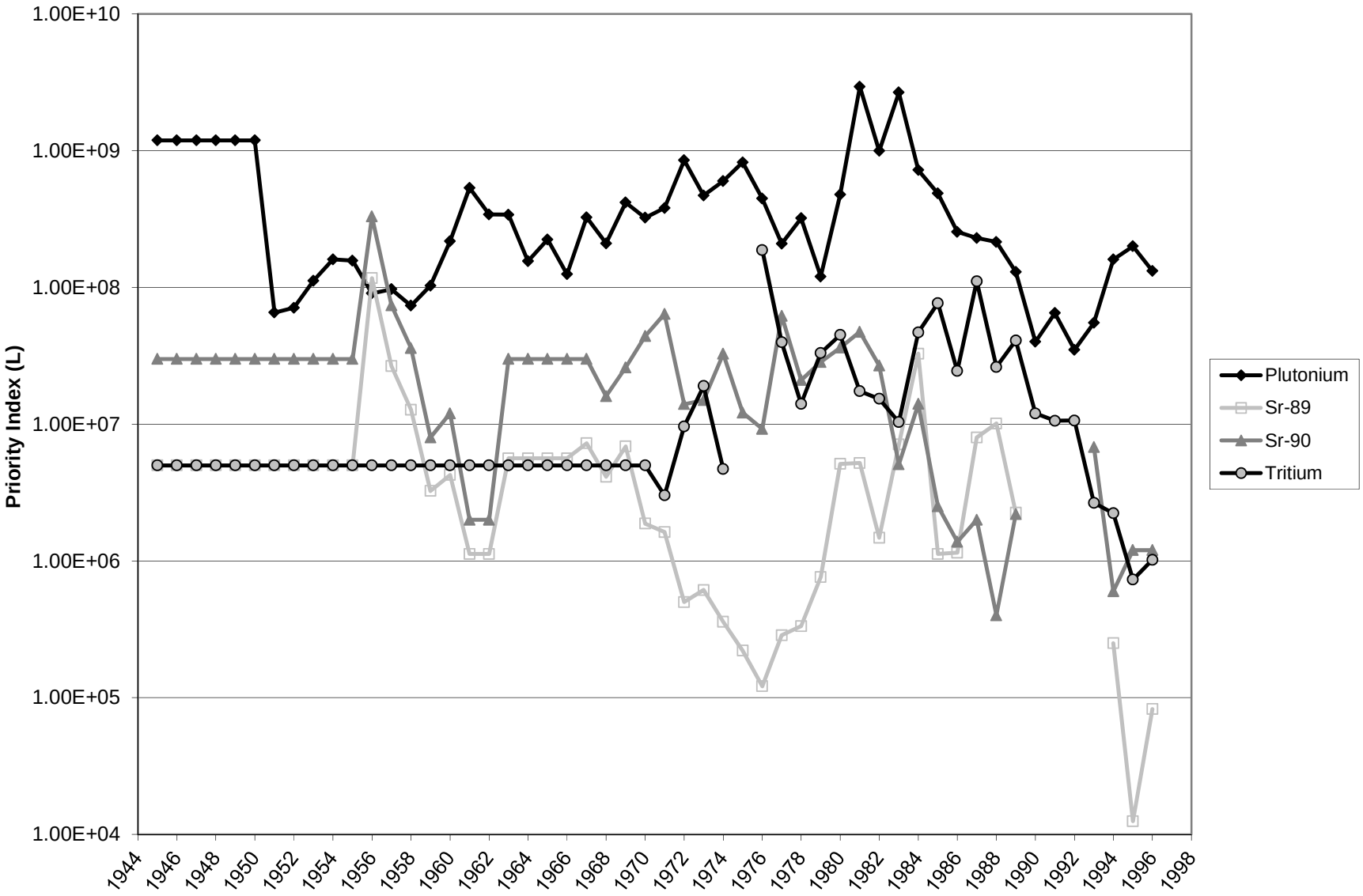


Fig. 17-20. Priority Indices for LANL Waterborne Radionuclide Releases

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Chapter 18: Screening-Level Evaluation of Airborne Plutonium Releases from DP West Site

Because airborne plutonium releases from DP West Site were documented to have been significantly higher than has been officially reported, and because residential areas were located quite close to the site, two screening-level evaluations using the methodology of the National Council on Radiation Protection and Measurements (NCRP) Report No. 123 (NCRP, 1996) were performed. Evaluations were performed for two eras to account for the fact residential areas became located closer to DP West over time. The first evaluation was performed for releases during 1949, which is the apparent year of peak emissions for the period prior to 1957. A second screening-level evaluation was performed for releases during 1959, the apparent year of peak emissions after 1957. The year 1957 is significant because it marks the appearance of the Group 18 housing area, resulting in a significant change in the proximity of the nearest residents to DP West.

The NCRP methodology uses three levels of screening calculations for atmospheric transport pathways. Level I screening uses the simplest approach and incorporates a high degree of conservatism to avoid underestimating doses. Level II screening accounts for dispersion in the atmosphere and combines all significant pathways into a single screening factor. Level III screening includes more definitive pathway analysis for inhalation, external exposure, and ingestion of terrestrial food products in the form of vegetables and/or animal food products.

DP West Site Releases used for the screening-level evaluation are based on annual release estimates presented in Chapter 17. The average ^{239}Pu release rates for 1949 and 1959 were calculated as follows: The annual exhaust volume of 1.88×10^9 m^3 y^{-1} for the Building 12 stack [see Fig. 18-1; (Andrews, ca. 1973)] was converted to 58.8 m^3 s^{-1} to support calculating the average plutonium concentration in the stacks.

For the screening-level evaluation of releases from the DP West Building 12 stacks in 1949, the closest potentially exposed members of the public were residents at the trailer park located 1km west of the stacks (see Fig. 18-2). In 1959, the closest potential exposed members of the public were 0.5 km northwest of the stacks. Based on the Level I screening method's assumption that

the wind blew toward the closest potentially exposed individual 25% of the time, concentrations at that point were estimated as one-quarter of the average stack concentration. The exposure point concentration (Bq m^{-3}) was multiplied by the all-pathways screening factor (Sv per Bq m^{-3}) from Table 1.1 of NCRP Report No. 123 to yield screening values that were compared to a limiting value.

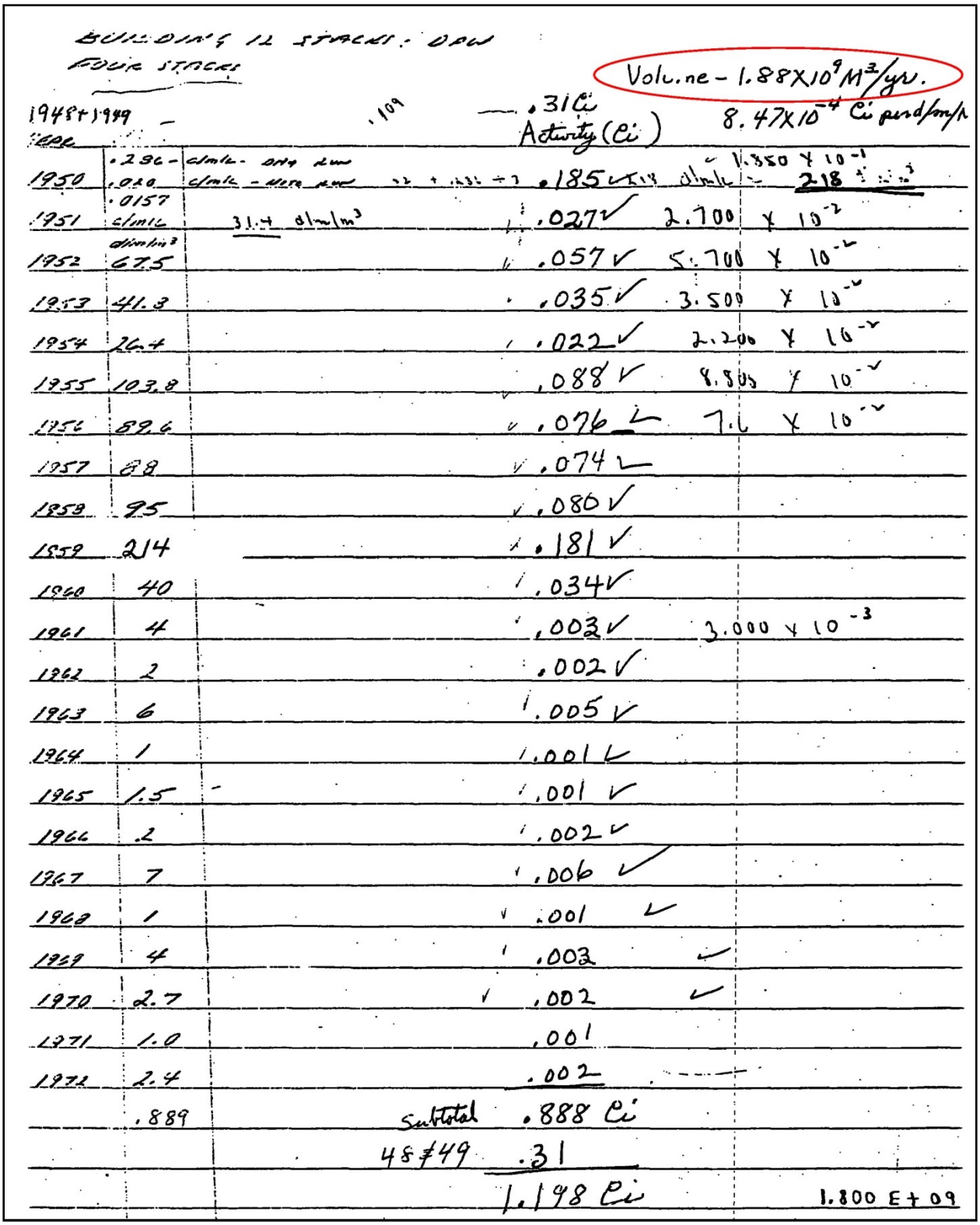

Fig. 18-1. Sheet showing exhaust flow volume and (uncorrected) annual releases from DP West Building 12 Stacks for 1948-1972 (Andrews, ca 1973). This handwritten sheet is the most basic documentation found of the 1.2-Ci release total that LANL reported in 1979 for operations before 1973.

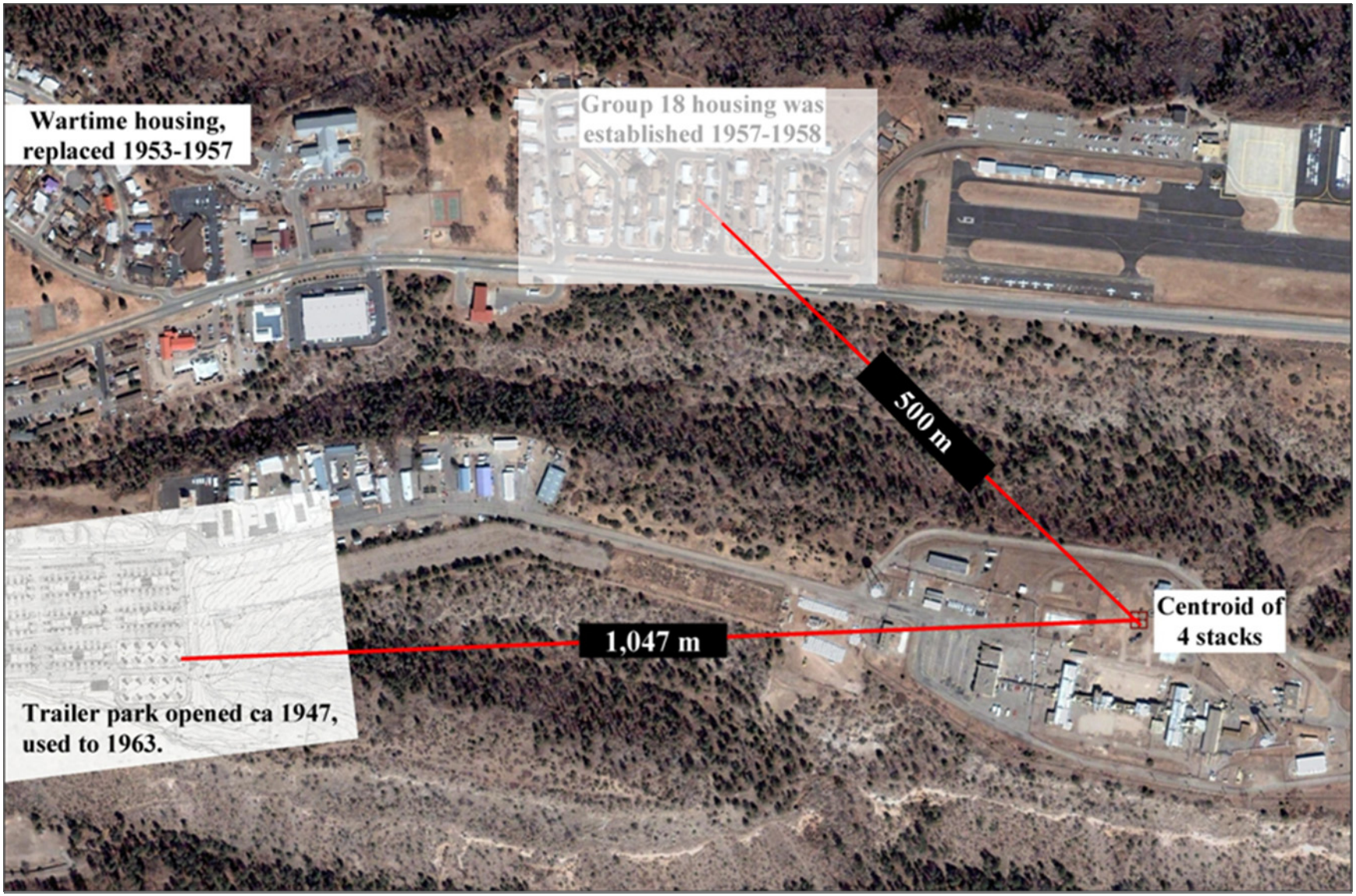

Fig. 18-2. Annotated modern aerial photograph showing former locations of DP West Site Building 12 stacks and nearby residential areas. Trailer park drawing is excerpted from USAEC Drawing LA FM 125 (Sheets L7-SW-1 and L6-SE-1).

For this screening assessment, the limiting value selected was 1.82×10^{-4} Sv y^{-1}, which is based on 1 in 100,000 added risk of fatal or non-fatal cancer using a risk factor of 5.5×10^{-2} Sv^{-1} (ICRP, 2007).

It is important to emphasize that the results of the screening calculations are strictly for comparison to an environmental standard (limiting value), to determine if compliance with that standard is assured, or if further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals.

For Level II screening, the release height was determined to be 58.6 ft above ground level based on LANL Drawing 12T35397A2 (See Fig. 18-3). The dimensions of the portion of Building 12 that housed the filters and precipitators and faced west were estimated to be 14.3 m high by 27.9 m wide (see Fig. 18-4) based on analysis of Photograph 2284 and a report documenting the building's demolition (Christensen et al., 1975).

The atmospheric concentration at the exposure point was estimated using Equation 1 with f = 0.25, $Q = 5.08\times10^{3}$ Bq s^{-1} [1949] or 3.25×10^{3} Bq s^{-1} [1959], and u equal to the suggested default value of 2 m s^{-1}.

$$C = \frac{f\,Q\,B}{u} \qquad (1)$$

Where:
- C = average atmospheric concentration at exposure point, μCi m^{-3}
- f = fraction of time that the wind blew toward the receptor of interest
- Q = release rate (μCi s^{-1})
- B = the Gaussian plume model diffusion factor modified for building wake effects (from Fig. 1.5 of NCRP Report No. 123)
- u = mean wind speed, m s^{-1}

The resulting concentration was multiplied by the atmospheric screening factor from Table 1.1 of NCRP Report No. 123 to obtain the Level II screening value. In accordance with NCRP

recommendations, that screening value was compared to 10% of the limiting value in recognition of uncertainties inherent within the calculations and associated assumptions.

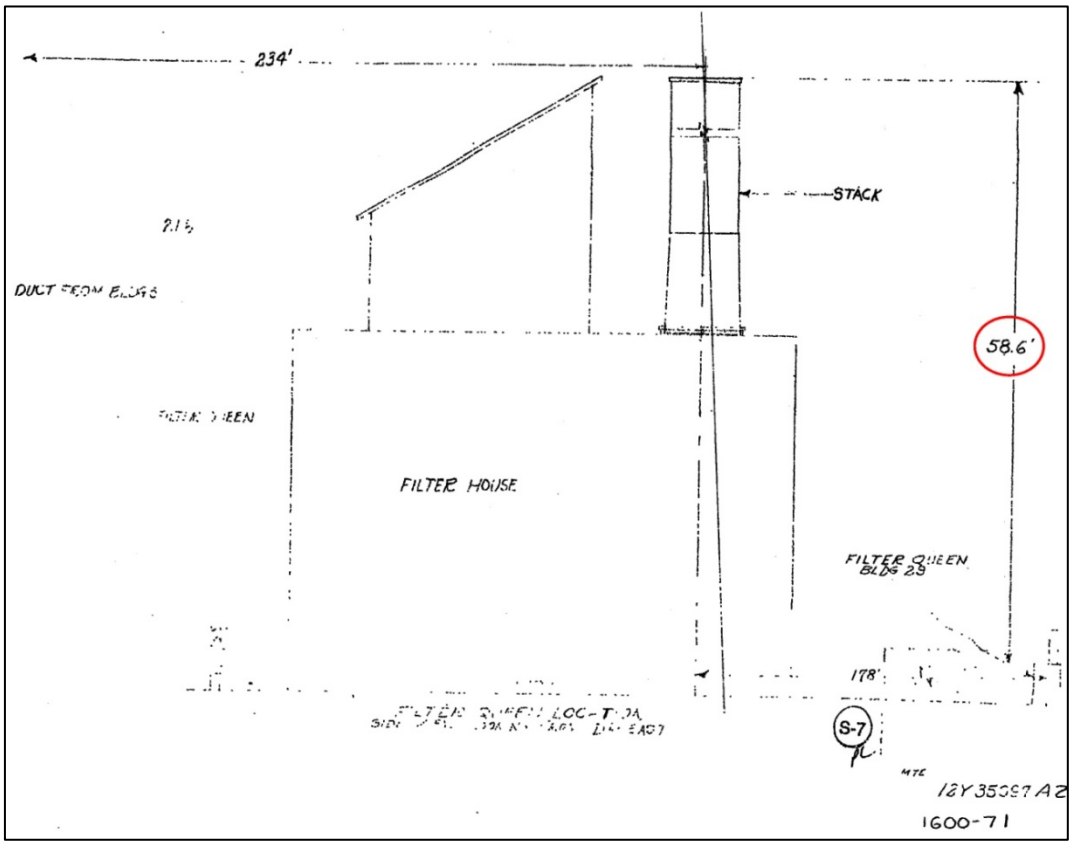

Fig. 18-3. Drawing of DP West Site Building 12 filter house and stacks

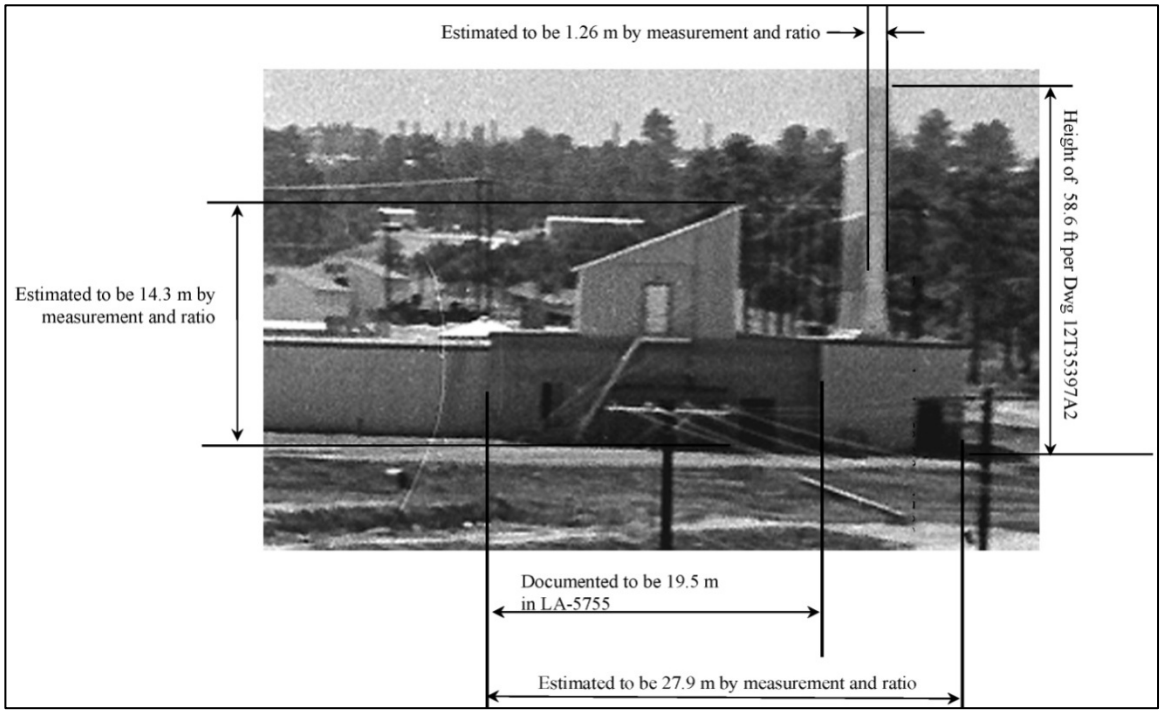

Fig. 18-4. Annotated section of Photograph 2284 showing Building 12 from the east

Historical documents and interviews with Los Alamos residents indicate that residents were allowed to maintain vegetable gardens after World War II, including at the trailer park west of DP Site, but no evidence has been found of any animal food product production within the townsite. The two screening values were summed and compared to the screening limit (i.e., the limiting value divided by ten as in Level II) to determine whether further evaluation of historical exposures is warranted. In Level III screening, the exposure point air concentration from Level II screening was multiplied by a screening factor for inhalation and external sources/submersion from Table 1.1 of NCRP Report No. 123, and by a second screening factor for vegetable consumption from the same table to obtain screening values for inhalation and external exposure, as well as for home grown vegetable consumption.

Screening Worksheets

Appendix 18-A are copies of the applicable worksheet pages used to apply the NCRP Report No. 123 screening method to the DP West Building 12 stack releases.

Results of the Screening

The results of preliminary screening of airborne ^{239}Pu releases from DP West site Building 12 stacks during 1949 and 1959 are presented in Table 18-1 and 18-2, respectively. In Level I and Level II screenings, the screening values for both years exceeded the limiting value prompting application of the screening methodology at the next highest level.

The results of the screening calculations are strictly for comparison to an environmental standard (limiting value), to determine if compliance with that standard is assured, or if further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals.

The results of the Level III screening indicate that airborne ^{239}Pu releases from Building 12 stacks – as represented by estimated releases during 1949 and 1959 – warrant further evaluation by experts in environmental radiological assessment.

Table 18-1. Summary of the preliminary screening of airborne ^{239}Pu releases from DP West Site Building 12 stacks during 1949 using the methodology of NCRP Report No. 123

Level of Screening	Features of Screening Methodology	Screening Value (Sv y^{-1})	Screening Limit exceeded?	NCRP Guidance
I	Vent air, all pathways, concentration at exposure point set equal to 25% of stack concentration.	21.3	Yes	Proceed to Level II
II	Vent air, all pathways, Gaussian plume modeling to exposure point outside near-wake region, wind blows toward exposure point 25% of the time.	0.025	Yes	Proceed to Level III
III	Vent air, specific pathways (inhalation, external exposure, consumption of vegetables), same dispersion assumptions as Level II.	0.025	Yes	"Seek assistance from experts in environmental radiological assessment"

Table 18-2. Summary of the preliminary screening of airborne ^{239}Pu releases from DP West Site Building 12 stacks during 1959 using the methodology of NCRP Report No. 123

Level of Screening	Features of Screening Methodology	Screening Value (Sv y^{-1})	Screening Limit exceeded?	NCRP Guidance
I	Vent air, all pathways, concentration at exposure point set equal to 25% of stack concentration.	13.6	Yes	Proceed to Level II
II	Vent air, all pathways, Gaussian plume modeling to exposure point outside near-wake region, wind blows toward exposure point 25% of the time.	0.061	Yes	Proceed to Level III
III	Vent air, specific pathways (inhalation, external exposure, consumption of vegetables), same dispersion assumptions as Level II.	0.061	Yes	"Seek assistance from experts in environmental radiological assessment"

References

Andrews LL. Los Alamos National Laboratory site releases up to 1972. Los Alamos Scientific Laboratory. ca. 1973.

Christensen E, Garde R, Valentine A. Demolition of Building 12, an old plutonium filter facility. Los Alamos, NM: Los Alamos National Laboratory; LA-5755; 1975.

ICRP. The 2007 Recommendations of the International Commission on Radiological Protection. Stockholm: The International Commission on Radiological Protection; ICRP 103; 2007.

NCRP. Screening Models for Release of Radionuclides to Atmosphere, Surface Water, and Ground. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 123; 1996.

Appendix 18-A: Copies of the applicable worksheet pages used to apply the NCRP Report No. 123 screening method

1.1 Atmosphere Screening Level I: Vent Air

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

I-A-1: Specify the radionuclide released by chemical symbol and atomic mass number (for example, ^{131}I).

I-A-2: Specify the release rate, Q, of the radionuclide entered in I-A-1. This release rate is obtained by estimating the amount released continuously or intermittently in 1 y (Bq y^{-1}) and dividing by the number of seconds in a year (3.2×10^7 s y^{-1}).

I-A-3: Enter the volumetric flow rate of the exhaust vent, V. If the volumetric flow rate of the exhaust vent is unknown, assume a value of 0.3 m^3 s^{-1}.

I-A-4: Calculate the air concentration in the exhaust vent, C_e, for the radionuclide by dividing the release rate (I-A-2) by the volumetric flow rate (I-A-3).

I-A-5: Assume that the wind blows only 25 percent of the time toward the potentially exposed individual. Multiply the values in I-A-4 by 0.25 to calculate the atmospheric concentration, C.

I-A-6: Select from Table 1.1 the all paths screening factor, SF, for the radionuclide entered in I-A-1. The value of SF includes the combined effects of all significant potential pathways of exposure.

I-A-7: Calculate the screening value, SV, by multiplying the atmospheric concentration (calculated in I-A-5) by the SF (I-A-6).

I-A-8: Sum the results in I-A-7 for all radionuclides for all sheets.

I-A-9: Enter the appropriate limiting value. This limiting value may be equivalent to a regulatory dose limit.

I-A-10: If the screening value of the dose estimate in I-A-8 is less than the limiting value entered in I-A-9, **compliance with the limiting value is assured.** If the value in I-A-8 is greater than the limiting value, **proceed to the next level of screening (Section 1.2).**

1-A-1:	Radionuclide	Pu-239	
I-A-2:	Release rate, Q	5.08E+03	Bq s^{-1} Pu-239

Bases: 4.39 Ci released in 1949

4.39 Ci × 3.7×10^{10} Bq Ci^{-1} ÷ 3.2×10^{7} s y^{-1} = 5.08×10^{3} Bq s^{-1} Pu-239

I-A-3:	Volumetric flow rate, *V*	59.68	m^3 s^{-1}
I-A-4:	Exhaust concentration: $C_e = Q V^{-1}$ (I-A-2)(I-A-3)$^{-1}$	85.1	Bq m^{-3} Pu-239
I-A-5:	Atmospheric concentration: $C = 0.25\ C_e$ 0.25 (I-A-4)	21.3	Bq m^{-3} Pu-239
I-A-6:	Enter Table 1.1 *SF* values for the radionuclide [Exhibit C shows the applicable portion of Table 1.1]	1.0×10^{0}	Sv per Bq m^{-3}
I-A-7:	Screening value: $SV = C \times SF$ (I-A-5) (I-A-6)	21.3	Sv y^{-1}
I-A-8:	Sum results for all radionuclides in I-A-7	21.3	Sv y^{-1}
I-A-9:	Limiting value	1.82E-04	Sv y^{-1}

Bases: Decision guide of 10^{-5} added risk of fatal or non-fatal cancer.
Added risk of cancer is 6.0×10^{-2} Sv^{-1} (ICRP, 1990)
Potential alternative limiting value is NRC limit of
1 mSv y^{-1} to a member of the general public (10CFR20.1301)

I-A-10:	Is I-A-8 less than I-A-9?	No	

Yes– STOP
No– Proceed to Section 1.2

1949 Screening-Level Calculation

1-A-1:	Radionuclide	Pu-239	
I-A-2:	Release rate, Q	3.25E+03	Bq s^{-1} Pu-239

Bases: 2.81 Ci released in 1959

2.81 Ci × 3.7×10^{10} Bq Ci^{-1} ÷ 3.2×10^{7} s y^{-1} = 3.25×10^{3} Bq s^{-1} Pu-239

I-A-3:	Volumetric flow rate, V	59.68	m^3 s^{-1}
I-A-4:	Exhaust concentration: $C_e = Q V^{-1}$ (I-A-2)(I-A-3)$^{-1}$	54.4	Bq m^{-3} Pu-239
I-A-5:	Atmospheric concentration: $C = 0.25 C_e$ 0.25 (I-A-4)	13.6	Bq m^{-3} Pu-239
I-A-6:	Enter Table 1.1 SF values for the radionuclide [Exhibit C shows the applicable portion of Table 1.1]	1.0×10^{0}	Sv per Bq m^{-3}
I-A-7:	Screening value: $SV = C \times SF$ (I-A-5) (I-A-6)	13.6	Sv y^{-1}
I-A-8:	Sum results for all radionuclides in I-A-7	13.6	Sv y^{-1}
I-A-9:	Limiting value	1.82E-04	Sv y^{-1}

Bases: Decision guide of 10^{-5} added risk of fatal or non-fatal cancer.
Added risk of cancer is 6.0×10^{-2} Sv^{-1} (ICRP, 1990)
Potential alternative limiting value is NRC limit of
1 mSv y^{-1} to a member of the general public (10CFR20.1301)

I-A-10:	Is I-A-8 less than I-A-9?	No

Yes– STOP
No– Proceed to Section 1.2

1959 Screening-Level Calculation

1.2 Atmosphere Screening Level II: All Pathways

II-bi: Basic Information, bi, Required for Completing Screening Levels II and III

(for description of parameters see Figure 1.3)

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

II-bi-1: Enter radionuclide from I-A-1 by chemical symbol and atomic mass number.

II-bi-2: Enter for the radionuclide the air concentration in the exhaust vent, C_e, as calculated in I-A-4.

II-bi-3: Determine the height above ground, H, at which the release will occur. This determination should exclude the effect of plume rise. If the release occurs in a narrow valley, use $H = 0$.

II-bi-4: Determine the height, h_b, and width, h_w, of the building most influencing the dispersion process. This should be the building on which the release point is located unless there is a much larger building in the immediate vicinity, in which case the latter building should be used for this purpose.

II-bi-5: For the building most influencing flow, determine the surface area, A_G, of the side of the building nearest the location of potential human exposure. Multiply the height of the building, h_b, by the width of the building side nearest the potential receptor, h_w.

II-bi-6: Determine the diameter of the stack or vent from which the radionuclide is being released. If the vent is other than circular, determine its equivalent circular diameter, d, by multiplying the area of the vent by 1.3 and taking the square root of the product.

II-bi-7: Determine the wind speed, u, at the release point. If data are not readily available, assume a value of 2 m s^{-1}.

II-bi-8: Determine the distance, x, between the release point and the nearest point routinely occupied by humans. **Proceed to II-A-1.**

II-bi-1:	Radionuclide from I-A-1	Pu-239	
II-bi-2:	Enter from I-A-4 the calculated concentration in the exhaust vent, C_e	85.1	Bq m^{-3} Pu-239
II-bi-3:	Release height, H	17.86	m

Bases: Stack tops are 58.6 feet above ground level [see Exhibit D, LASL Drawing 12T35397A2]
58.6 ft x 0.3048 m ft^{-1} = 17.86 m

II-bi-4:	Building height, h_b	14.3	m
	and building width, h_w	27.9	m

Bases: Stated size of the portion of the building that housed the filters and precipitators was 30.9 m by 19.5 m (from LA-5755 by Christensen et al. 1975).
Width of that portion plus the stack blower portion estimated using side view Photo # 2284 [Exhibit E].

II-bi-5:	Building surface area: $A_G = h_b h_w$	399	m^2
II-bi-6:	Diameter of stack or vent, d	1.07	m

Bases: Drawing ENG-C 2307 dated May 17, 1945 states diameter was 42 inches =1.07 m

II-bi-7:	Wind speed, u	2	m s^{-1}
II-bi-8:	Distance from release point to point of exposure, x	1047	m

Bases: Distance from centroid of Building 12 stacks to nearest residence in Group 18 housing just west of the Los Alamos airport using Google Earth.

Proceed to II-A-1

1949 Screening-Level Calculation

II-bi-1:	Radionuclide from I-A-1	Pu-239	
II-bi-2:	Enter from I-A-4 the calculated concentration in the exhaust vent, C_e	54.4	Bq m^{-3} Pu-239
II-bi-3:	Release height, H	17.86	m

Bases: Stack tops are 58.6 feet above ground level [see Exhibit D, LASL Drawing 12T35397A2]
58.6 ft x 0.3048 m ft^{-1} = 17.86 m

II-bi-4:	Building height, h_b	14.3	m
	and building width, h_w	27.9	m

Bases: Stated size of the portion of the building that housed the filters and precipitators was 30.9 m by 19.5 m (from LA-5755 by Christensen et al. 1975).
Width of that portion plus the stack blower portion estimated using side view Photo # 2284 [Exhibit E].

II-bi-5:	Building surface area: $A_G = h_b h_w$	399	m^2
II-bi-6:	Diameter of stack or vent, d	1.07	m

Bases: Drawing ENG-C 2307 dated May 17, 1945 states diameter was 42 inches =1.07 m

II-bi-7:	Wind speed, u	2	m s^{-1}
II-bi-8:	Distance from release point to point of exposure, x	500	m

Proceed to II-A-1

1959 Screening-Level Calculation

II-A: Initial Decisions

II-A-1: If the release point and the exposure point are both located (a) on the roof, or (b) on the same side of the building, or (c) in the same building, or confinement of the plume is important, **proceed to Section II-B.**
If none of these conditions apply, **proceed to II-A-2.**

II-A-2: Multiply the building height, h_b, in II-bi-4 by 2.5. The result will be used to determine the effect of the building on the atmospheric dispersion of the released radionuclide(s). Enter the release height, H. Compare the result of the multiplication with H.
If H in II-bi-3 is greater than 2.5 times h_b, **proceed to Section II-C.** This condition represents the case where the building will not affect atmospheric dispersion. In this case proceed to II-C.
If H is less than or equal to 2.5 times h_b, **proceed to II-A-3**. This condition represents the case where the building will affect atmospheric dispersion.

II-A-3: To determine which type of atmospheric dispersion model should be used for situations in which building wakes are formed, take the square root of the building surface area, A_G, (II-bi-5) and multiply the result by 2.5.
If the distance, x, between the point of release and the nearest point of exposure (II-bi-8) is equal to or less than 2.5 times the square root of A_G, or is equal to or less than 100 m **proceed to Section II-D.** This condition represents the case where the receptor is in the near-wake region of the building.
If the distance, x, between the point of release and the nearest point of exposure (II-bi-8) is greater than 2.5 times the square root of A_G, and greater than 100 m **proceed to Section II-E.** This condition represents the case where the receptor is outside the near-wake region of the building.

II-A-1:	Are the point of release and the potentially exposed individual located as described on the preceding page?	No	

Yes– Proceed to Section II-B
No– Proceed to Section II-A-2

II-A-2	h_b (II-bi-4)	14.3	m
	2.5 h_b =	36	m
	H (II-bi-3)	17.86	m
	Is H greater than 2.5 h_b ?	No	

Yes– Proceed to Section II-C
(no building wakes)
No– Proceed to Section II-A-3
(building wakes)

II-A-3:	A_G (II-bi-5)	399	m^2
	2.5 $A_G^{1/2}$ =	50	m
	x (II-bi-8)	1047	m
	Is x equal to or less than 2.5 $A_G^{1/2}$ or equal to or less than 100 m?	No	

Yes– Proceed to Section II-D
(near wake region)
No– Proceed to Section II-E
(outside near-wake region)

1949 Screening-Level Calculation

II-A-1:	Are the point of release and the potentially exposed individual located as described on the preceding page?	No	

Yes– Proceed to Section II-B
No– Proceed to Section II-A-2

II-A-2	h_b (II-bi-4)	14.3	m
	2.5 h_b =	36	m
	H (II-bi-3)	17.86	m
	Is H greater than 2.5 h_b ?	No	

Yes– Proceed to Section II-C
(no building wakes)
No– Proceed to Section II-A-3
(building wakes)

II-A-3:	A_G (II-bi-5)	399	m^2
	2.5 $A_G^{1/2}$ =	50	m
	x (II-bi-8)	500	m
	Is x equal to or less than 2.5 $A_G^{1/2}$ or equal to or less than 100 m?	No	

Yes– Proceed to Section II-D
(near wake region)
No– Proceed to Section II-E
(outside near-wake region)

1959 Screening-Level Calculation

II-E: Receptor Outside the Near-Wake Region of Building

Condition: Distance to exposure point is greater than 2.5 times the square root of the building surface area, A_G, and greater then 100 m.

II-E-1: If the downwind distance to the nearest point of potential human exposure, x, is less than 2 km from the point of release, use Figure 1.5 to determine the value of the building wake dispersion factor, B, corresponding to the building surface area, A_G, given in II-bi-5 and x in II-bi-8.
If the downwind distance, x, to the nearest point of potential human exposure is greater than 2 km from the point of release, use Figure 1.4, assuming a release height at ground level, or 0 m. Substitute the value P from Figure 1.4 for the building wake dispersion factor.

II-E-2: Enter radionuclide, release rate, Q, and wind speed, u. To calculate the downwind atmospheric concentration for each radionuclide for the potentially exposed individual, assume that the wind blows 25 percent of the time toward the potentially exposed individual. Multiply the release rate from I-A-2 by the dispersion factor, B or P, in II-E-1 and by 0.25; then divide by the wind speed, u, given in II-bi-7. However, if $u > 5$ ms^{-1}, use $u = 5$ ms^{-1} in this calculation.

Enter the calculated atmospheric concentration, and **proceed to Section II-F.**

II-E-1:	Dispersion factor B from Fig. 1.5 or P from Fig. 1.4 [see Exhibits G and H]	4.00E-05	m^{-2}
II-E-2:	Radionuclide (II-bi-1)	Pu-239	
	Release rate, Q (I-A-2)	5.08E+03	Bq s^{-1} Pu-239
	Wind speed, u (II-bi-7)	2	m s^{-1}
	Atmospheric concentration: $C = 0.25\ Q\ (B \text{ or } P)\ u^{-1}$ [0.25 (I-A-2) (II-E-1)] (II-bi-7)$^{-1}$	2.54E-02	Bq m^{-3} Pu-239

Proceed to Section II-F

1949 Screening-Level Calculation

II-E-1:	Dispersion factor B from Fig. 1.5 or P from Fig. 1.4 [see Exhibits G and H]	1.50E-04	m^{-2}
II-E-2:	Radionuclide (II-bi-1)	Pu-239	
	Release rate, Q (I-A-2)	3.25E+03	Bq s^{-1} Pu-239
	Wind speed, u (II-bi-7)	2	m s^{-1}
	Atmospheric concentration: $C = 0.25\ Q\ (B \text{ or } P)\ u^{-1}$ [0.25 (I-A-2) (II-E-1)] (II-bi-7)$^{-1}$	6.09E-02	Bq m^{-3} Pu-239

Proceed to Section II-F

1959 Screening-Level Calculation

II-F: Comparison of Screening Value Using Screening Limiting Dose

II-F-1: Enter the radionuclide from II-bi-1. Enter the atmospheric concentration calculated for the radionuclide from Section II-B-1, II-B-2, II-C-2, II-D-1, or II-E-2, depending on atmospheric concentration model used.

II-F-2:. Enter from Table 1.1 the all paths screening factor, *SF*, for the radionuclide.

II-F-3: Multiply the atmospheric concentration entered in II-F-1 by the atmospheric screening factor entered in II-F-2 to obtain the screening value, *SV*.

II-F-4: Sum the results in II-F-3 for all sheets and all radionuclides.

II-F-5: Take the limiting value from I-A-9, divide by 10, and enter. (Note: There are uncertainties inherent within the calculations and assumptions made in this Section. Dividing this limiting value by a factor of 10 reduces the possibility of exceeding the limiting value because of these uncertainties.)

II-F-6: If II-F-5 is greater than II-F-4, **compliance with the limiting value is assured.**
If the value in II-F-5 is equal to or less than II-F-4, **proceed to Screening Level III.**

II-F-1:	Radionuclide from II-bi-1	Pu-239	
	Atmospheric concentration, *C,* from II-B-1, II-B-2, II-C-2, or II-E-2	2.54E-02	Bq m^{-3} Pu-239
II-F-2:	Atmospheric screening factor, *SF*, from Table 1.1 for each radionuclide	1 x 10^{0}	Sv per Bq m^{-3}
II-F-3:	Calculate screening value: *SV = C SF* (II-F-1) (II-F-2)	2.54E-02	Sv y^{-1}
II-F-4:	Sum the results in II-F-3 for all sheets and radionuclides	2.54E-02	Sv y^{-1}
II-F-5:	(I-A-9) × 0.1	1.82E-05	Sv y^{-1}
II-F-6:	Is II-F-5 greater than II-F-4?	No	

Yes– STOP
No– Proceed to Screening Level III

1949 Screening-Level Calculation

II-F-1:	Radionuclide from II-bi-1	Pu-239	
	Atmospheric concentration, *C*, from II-B-1, II-B-2, II-C-2, or II-E-2	6.09E-02	Bq m^{-3} Pu-239
II-F-2:	Atmospheric screening factor, *SF*, from Table 1.1 for each radionuclide	1 x 10^{0}	Sv per Bq m^{-3}
II-F-3:	Calculate screening value: *SV = C SF* (II-F-1) (II-F-2)	6.09E-02	Sv y^{-1}
II-F-4:	Sum the results in II-F-3 for all sheets and radionuclides	6.09E-02	Sv y^{-1}
II-F-5:	(I-A-9) × 0.1	1.82E-05	Sv y^{-1}
II-F-6:	Is II-F-5 greater than II-F-4?	No	

Yes– STOP
No– Proceed to Screening Level III

1959 Screening-Level Calculation

1.3 Atmosphere Screening Level III: Specific Pathways

III-A: Calculation of Inhalation and External Exposure

Condition: It is assumed that inhalation and external exposure pathways always exist at the location corresponding to distance, x, given in II-bi-8.

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

III-A-1: Enter the radionuclide and the calculated atmospheric concentration from Section II-F-1 for the downwind distance, x.

III-A-2: For each radionuclide, enter the screening factor given in Table 1.1. These factors include the combined effects of internal exposure through inhalation and external exposure to the contaminated plume and ground surface.

III-A-3: Estimate the screening dose from inhalation and external sources of exposure. Multiply the atmospheric concentration entered in III-A-1 by the screening factor entered in III-A-2.

Sum the results for the screening dose.

III-A-1:	Radionuclide from II-F-1	Pu-239	
	Atmospheric concentration, *C*, from II-F-1	2.54E-02	Bq m^{-3} Pu-239
III-A-2:	Screening factor, *SF*, from Table 1.1	0.55	Sv per Bq m^{-3}
III-A-3:	Screening value for inhalation and external exposure for each radionuclide: $SV = C\ SF$ (II-A-1) (II-A-2)	1.40E-02	Sv y^{-1}
	Sum of results for all radionuclides and for all sheets	1.40E-02	Sv y^{-1}

1949 Screening-Level Calculation

III-A-1:	Radionuclide from II-F-1	Pu-239	
	Atmospheric concentration, *C*, from II-F-1	6.09E-02	Bq m^{-3} Pu-239
III-A-2:	Screening factor, *SF*, from Table 1.1	0.55	Sv per Bq m^{-3}
III-A-3:	Screening value for inhalation and external exposure for each radionuclide: $SV = C\ SF$ (II-A-1) (II-A-2)	3.35E-02	Sv y^{-1}
	Sum of results for all radionuclides and for all sheets	3.35E-02	Sv y^{-1}

1959 Screening-Level Calculation

III-B: Exposure *via* the Ingestion of Terrestrial Food Products

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

III-B-1: Enter radionuclide from III-A-1.

III-B-2: For conditions where pasture and/or vegetable gardens exist at the receptor location (distance x) given in II-bi-8, enter the atmospheric concentration from III-A-1 for the food categories that may be produced at this location. Enter zero for the food categories that are not likely to be produced at this location. If all the values entered are greater than zero, skip III-B-3 and **proceed to III-B-4.**
If some of the values entered are zero, go to next step.

III-B-3: For food categories that are not produced at the location (distance x) given in II-bi-8: (a) Determine the straight-line distance between the nearest potential production location of each food category and the point of release. (b) Return to the beginning of Section II. (c) Specify new values of x in II-bi-8 for the nearest potential production locations of each food category. (d) Recalculate the atmospheric concentration in either II-C, II-D or II-E for each food category. (e) Enter the recalculated atmospheric concentration for each food category. (Note: The atmospheric concentration will be used to calculate the concentration of radionuclide in terrestrial food products at the nearest specified sites of potential food production.)

III-B-1: Radionuclide from II-A-1 — Pu-239

III-B-2: Can vegetable gardens and/or pastures occur at location *x* (II-A-1)?

Yes– For each food category potentially produced at location x, enter the atmospheric concentration from III-A-1 in blanks below.

No– Enter zero in blanks below for the atmospheric concentration for the food categories not produced at location x and go to next step.

Vegetables	2.54E-02	Bq m^{-3} Pu-239
Animal food products	0	Bq m^{-3} Pu-239

If all the above values are greater than zero– **Proceed to III-B-4**

III-B-3: (a) Determine distance to the point of nearest production for each food category
(b) Return to Section II.
(c) Specify *x* in II-bi-8 for each food category.
(d) Recalculate atmospheric concentrations for each food category.
(e) Enter recalculated atmospheric concentration from either II-C, II-D, or II-E for each radionuclide and food category in the blanks below.

Vegetables		Bq m^{-3}
Animal food products		Bq m^{-3}

1949 Screening-Level Calculation

III-B-1: Radionuclide from II-A-1 — Pu-239

III-B-2: Can vegetable gardens and/or pastures occur at location *x* (II-A-1)?

Yes– For each food category potentially produced at location x, enter the atmospheric concentration from III-A-1 in blanks below.

No– Enter zero in blanks below for the atmospheric concentration for the food categories not produced at location x and go to next step.

Vegetables — 6.09E-02 Bq m^{-3} Pu-239

Animal food products — 0 Bq m^{-3} Pu-239

If all the above values are greater than zero– **Proceed to III-B-4**

III-B-3: (a) Determine distance to the point of nearest production for each food category
(b) Return to Section II.
(c) Specify *x* in II-bi-8 for each food category.
(d) Recalculate atmospheric concentrations for each food category.
(e) Enter recalculated atmospheric concentration from either II-C, II-D, or II-E for each radionuclide and food category in the blanks below.

Vegetables _____ Bq m^{-3}

Animal food products _____ Bq m^{-3}

1959 Screening-Level Calculation

III-B-4: Calculate the concentration of the radionuclide in terrestrial food products.
Enter value for the concentration of the radionuclide in the atmosphere at the nearest potential sites of vegetable production, and milk and meat production. These values should be obtained from either III-B-2 or III-B-3.

III-B-5: Estimate the screening value from the ingestion of terrestrial foods.

(a) For each radionuclide and food product, enter appropriate screening factor from Table 1.1.

(b) Multiply the atmospheric concentration of the radionuclide (estimated in III-B-4) by the radionuclide-specific screening factors.

(c) Sum the results to obtain the total ingestion screening value. **Proceed to III-C.**

III-B-4: Enter radionuclide from III-B-1	Pu-239	
Enter atmospheric concentration, *C*, from either III-B-2 or III-B-3		
Vegetables	2.54E-02	Bq m^{-3} Pu-239
Animal food products	0	Bq m^{-3} Pu-239
III-B-5: (a) Enter appropriate screening factor, *SF*, from Table 1.1		
Vegetables	0.45	Sv per Bq m^{-3}
Animal food products	0	Sv per Bq m^{-3}
(b) Screening value: $SV = C \times SF$ (II-B-4) (III-B-5)		
Vegetables	1.14E-02	Sv
Animal food products	0	Sv
(c) Sum the results to obtain the total screening value from ingestion of radionuclide	1.14E-02	Sv

Proceed to III-C

1949 Screening-Level Calculation

III-B-4: Enter radionuclide from III-B-1 — Pu-239

Enter atmospheric concentration, *C*, from either III-B-2 or III-B-3

Vegetables — 6.09E-02 Bq m^{-3} Pu-239

Animal food products — 0 Bq m^{-3} Pu-239

III-B-5: (a) Enter appropriate screening factor, *SF*, from Table 1.1

Vegetables — 0.45 Sv per Bq m^{-3}

Animal food products — 0 Sv per Bq m^{-3}

(b) Screening value: $SV = C \times SF$
(II-B-4) (III-B-5)

Vegetables — 2.74E-02 Sv

Animal food products — 0 Sv

(c) Sum the results to obtain the total screening value from ingestion of radionuclide — 2.74E-02 Sv

Proceed to III-C

1959 Screening-Level Calculation

III-C: Receptor Exposed to Pathways from Multiple Locations

Condition: The hypothetical individual residing at the location (distance x) in III-A-1 is assumed to have access to contaminated foods at the potential sites of production nearest the point of release.

III-C-1: Calculate the screening value from all pathways.

(a) Enter from III-A-3 the total screening value calculated for inhalation and external sources of exposure.

(b) Enter the total screening value calculated in III-B-5 for ingestion of contaminated food.

(c) Add the inhalation and external screening values entered in III-C-1(a) to the ingestion doses in III-C-1(b) to calculate the total screening value from all pathways of exposure.

III-C-2: Enter the screening limiting value from II-F-5.

III-C-3: If the total screening value from all pathways in III-C-1(c) is less than the screening limit in III-C-2, **compliance with the limiting value is assured.**
If III-C-1(c) is equal to or greater than III-C-2 , **seek assistance from experts in environmental radiological assessment.**

III-C-1:	(a) Enter III-A-3: external and inhalation screening value	1.40E-02	Sv
	(b) Enter III-B-5: screening value from ingestion	1.14E-02	Sv
	(c) Sum external, inhalation, ingestion screening values: [III-C-1(a)] + [III-C-1(b)]	2.54E-02	Sv
III-C-2:	Enter II-F-5: screening limit	1.82E-05	Sv
III-C-3:	Is III-C-1(c) less than III-C-2?	No	

Yes– STOP
No– Seek expert assistance

1949 Screening-Level Calculation

III-C-1:	(a) Enter III-A-3: external and inhalation screening value	3.35E-02	Sv
	(b) Enter III-B-5: screening value from ingestion	2.74E-02	Sv
	(c) Sum external, inhalation, ingestion screening values: [III-C-1(a)] + [III-C-1(b)]	6.09E-02	Sv
III-C-2:	Enter II-F-5: screening limit	1.82E-05	Sv
III-C-3:	Is III-C-1(c) less than III-C-2?	No	

Yes– STOP
No– Seek expert assistance

1959 Screening-Level Calculation

Chapter 19: Prioritization of Chemical Releases from LANL

LANL operations have involved many non-radioactive materials, including metals, inorganic chemicals, and organic chemicals, including solvents. For the sake of simplicity in this report, we will refer to all of these materials as "chemicals." Prior to the 1970s, chemical use and their ultimate fate were poorly tracked and documented compared to radionuclides. For this reason, one particularly challenging portion of the LAHDRA project has been collecting information concerning historical uses of chemicals, identifying those that were most likely released off site, and determining which have been most important in terms of potential off-site health hazards.

Sources of Information Regarding Historical Chemical Usage

The sources of information about chemical usage at LANL that have been most useful to the LAHDRA team include a modern-day chemical inventory, historical chemical inventories, and various types of LANL site documents.

Current Chemical Inventory

Fig. 19-1. Personnel involved in early explosives testing at Los Alamos.

LANL maintains an inventory of chemicals present on-site to comply with annual environmental reporting requirements for hazardous chemical emissions. Information on the quantities and types of chemicals used at LANL was collected starting in 1991, and a Microsoft® Access database was completed in 1993 (Personal communication, Environmental Health and Safety Division (ES-5), 1999). The initial tracking system, called the Automated Chemical Inventory System (ACIS) had been updated annually since 1994. Recently, though, the inventory system was changed to the Injury Illness and Chemical Management Online Application by E3. Although the project team was granted access and training for the new system, the initial analysis of chemical inventory data conducted in 2000 was not repeated because of the limited usefulness of recent chemical inventory data for evaluating historical emissions of chemicals from LANL.

The ACIS database includes the following fields:

- Chemical name, CAS number, and bar code
- Location of chemical (technical area, building)
- Quantity, units of measure, and physical state (solid, liquid, gas)

ACIS is available on the internal LANL Web site using a SecureID card. Access to the database allows the data to be compiled in different ways, and provides details, such as the specific locations of chemicals through database search capabilities. A paper copy of the ACIS Microsoft® Access database file was provided to the project team by the ESH-5 group on January 26, 1999. At that time, the database contained approximately 120,000 records. Subsequently, access through a Web interface was granted to allow limited searches to be performed. A request for an official-use-only copy of the database for performing more complex searches was granted. However, the database does not include radionuclides, explosives, beryllium, depleted uranium, or other bulk metals. It contains many trade name products, without any information indicating whether they include any hazardous materials. The database also does not include any information regarding how the chemicals are used or their potential for release to the environment.

Preliminary review of the ACIS database indicates that 37 chemicals were each present onsite at 250 or more individual locations, and, therefore, represent the largest onsite quantities of chemicals. Twelve of the thirteen chemicals present onsite in the highest quantities do not have USEPA recommended toxicity values for potential cancer and non-cancer systemic health effects, although some can be irritants or corrosives at high concentrations. The 37 high quantity chemicals selected from ACIS are shown in Table 19-1 in order of decreasing estimated on-site quantities.

Of the 37 high quantity chemicals, the 13 with USEPA recommended toxicity values are shown in Table 19-1, ranked in order of generic toxicity, "1" being more toxic than "13." Generic toxicity includes both cancer and non-cancer chronic health effects, with no bias toward any route of potential exposure (e.g., inhalation, ingestion, and dermal contact), or to any potential environmental exposure medium (e.g., air, soil, water, food products), since little is known about how the chemicals were used and their potential for off-site release.

LANL personnel suggested that site files of Material Safety Data Sheets could be reviewed for trade name products to determine if any of them contained any hazardous materials. An analysis of the remaining inventory chemicals not included in Table 19-1 could be conducted in future phases of the dose

reconstruction to further prioritize recent chemical use at LANL. For chemicals that could be released to the off-site environment as a result of their use, air

Table 19-1. Selected data from a current LANL chemical inventory

Chemical	Onsite Quantity	Toxicity Ranking
Nitrogen	4.2×10^7 L	--
Argon	3.8×10^7 L	--
Helium	3.7×10^7 L	--
Hydrogen	1.6×10^6 L	--
Oxygen	1.6×10^6 L	--
Propane	1.3×10^5 L	--
Sulfuric acid	2.2×10^4 L	--
Toluene	2.1×10^4 L	8
Sodium hydroxide	1.5×10^4 kg	--
Sodium chloride	8.6×10^3 kg	--
Ethyl alcohol	7.1×10^3 L	--
Sodium carbonate	6.8×10^3 kg	--
Hydrochloric acid	6.6×10^3 L	--
Acetone	6.2×10^3 L	7
Ethylene glycol	5.1×10^3 L	12
Chlorodifluoromethane	4.8×10^3 L	14
Methyl alcohol	2.8×10^3 L	10
Nitric acid	2.6×10^3 L	--
Isopropanol	2.2×10^3 L	--
Hydrogen peroxide	7.8×10^2 L	--
Buffer solutions	6.3×10^2 L	--
Acetic acid	5.8×10^2 L	--
Hexane	5.4×10^2 L	5
Methylene chloride	4.9×10^2 L	4
Miscellaneous chlorofluorcarbon products	4.6×10^2 L	--
1,1,1,2-Tetrafluoroethane	4.4×10^2 L	--
Photographic developer products	3.9×10^2 L	--
Dimethyl sulfoxide	3.8×10^2 L	--
Chloroform	3.4×10^2 L	1
Benzene	2.1×10^2 L	2
Ether	2.0×10^2 L	9
Dichlorodifluoromethane	1.5×10^2 L	6
Photographic fixer products	1.2×10^2 L	--
Tetrahydrofuran	6.0×10^1 L	3
Ethylenediamine tetraacetic acid	3.8×10^1 kg	--
Ethyl acetate	2.1×10^1 L	11
1,1-Difluoroethane	8.5×10^0 L	13

dispersion and other transport models and exposure models can be used to estimate an onsite threshold quantity that would not result in adverse health impacts to off-site populations using site-specific assumptions regarding dispersion, transport and exposure. The threshold quantity approach could be used to focus data gathering efforts on those chemicals for which the on-site inventory quantity exceeds the threshold quantity. However, the chemical inventory database only contains information on selected chemicals present at LANL since 1991.

Historical Chemical Inventories

Harry Schulte, a former LANL Industrial Hygiene group leader, is reported to have conducted a chemical inventory in the early 1970s (Personal communication, Environmental Health and Safety Division (ES-5), 1999). A draft report was prepared, but was never finalized. While the LAHDRA team was told that the draft report and supporting data might be located in the Industrial Hygiene group files in the Central Records Center, surviving members of Mr. Schulte's group reportedly do not have any copies in their possession. This 1970s chemical inventory information has not been located by the project team to date.

For years prior to initiating the current chemical inventory program, the project team identified several lists of chemicals used at LANL in years prior to 1980s environmental reporting requirements. The lists represent the years 1947-50 (LANL 1948), 1971 (Blackwell 1971, Schulte 1972), and 1970s (LASL 1977a, Volez 1977, Hansen and Ferenbaugh 1982). Quantities and locations of use are typically not provided in these lists. The project team identified considerable documentation related to chemical use in specific areas for the 1980s and 1990s as LANL began collecting these data in response to regulatory requirements.

Table 19-2 lists chemicals documented as having been used at LANL at some point in time. This list was compiled from the LANL documents reviewed to date, entered into the project database, and released to the public. Documents used to identify the chemicals in Table 19-2 are included in the reference section, and are described below.

Table 19-2. Chemicals historically used at LANL

Elements	**Inorganics**
aluminum	asbestos (magnesium silicate)
antimony	bromide
arsenic	cyanide
barium	hydrochloric acid
beryllium	hydrofluoric acid
bromine	nitric acid
cadmium	oxalic acid/ oxalate
chromium	perchloric acid/ perchlorate
copper	phosphoric acid
dioxane	sodium hydroxide
fluoride	sodium thiosulfate
gallium	sulfuric acid
iron	
lanthanum	**Semi-Volatile Organics**
lead	n-butyl acetate
lithium	ethyl acetate
manganese	ethylene glycol
mercury	hexachlorobutadiene
molybdenum	naphthalene
nickel	PCB (polychlorinated biphenyls): Aroclor 1242
niobium	
platinum	**Explosives**
samarium	Baratol (mixture of barium nitrate and TNT)
silver	Comp. B (mixture of 60% RDX and 40% TNT)
tantalum	Cyclotol (mixture of 70-75% RDX and 25-30% TNT)
thallium	Explosive D (ammonium picrate; ammonium-1,3,5-trinitrophenol)
uranium (normal and depleted)	HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
vanadium	nitrobenzene
zinc	nitrocellulose
zirconium	nitromethane
	NQ (nitroguanidine; Picrite)
Volatile Organic Compounds	Octol (mixture of 70-75% HMX and 25-30% TNT)
acetone	PBX
benzene	Pentolite
carbon tetrachloride	PETN (pentaerythritol tetranitrate)
chloroform	picric acid
chlorodifluoromethane	PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine)
dichlorodifluoromethane	RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine)
difluoroethane	Saltex
ethanol	TATB (1,3,5-triamino-2,4,6-trinitrobenzene)
ether	Tetryl (1,3,5-trinitrophenyl-methylnitramine)
isopropanol	TNT (2,4,6-trinitrotoluene)
kerosene	Torpex
methanol	
methyl chloride (chloromethane)	
methyl ethyl ketone (2-butanone)	
methylene chloride (dichloromethane)	
tetrachloroethylene	
tetrabromoethane	
tetrahydrofuran	
toluene (toluol)	
trichloroethane	
trichloroethylene	
xylene	

Table 19-3 is a compilation of data located by the project team regarding quantities of chemicals used or released historically from LANL. Five documents report quantities of primarily volatile organic solvents that were used at LANL from 1971 until 1985. Three documents identify chemical quantities as "released or lost to the atmosphere." One of the three documents, a report on airborne effluents, is a third source of the same numbers provided in Repos. Nos. 610 and 1324 (LASL 1973a, Valentine 1973, LASL 1977b). It states that the amount of airborne solvents is taken from LANL stock issue records. However, volatile solvents will, in time, most likely become airborne, no matter what the disposal method; 100% volatilization was therefore assumed. The chemicals listed in Table 19-3 are listed in the order of quantity used or released. Selection of the chemicals addressed in these documents was based on state and federal air pollution requirements at the time of reporting. From Table 19-3, it can be concluded that trichloroethane and trichloroethylene were the most used volatile organic chemicals at LANL in the early 1970s. However, trichlorethylene appears to have been replaced by freons in the early 1980s. Methyl ethyl ketone was also used in high quantities until 1982.

Site Documents

In the late 1980s, the Senate Committee on Armed Services asked the Office of Technology Assessment to evaluate what was known about the contamination and public health problems at the Nuclear Weapons Complex (U.S. Congress 1991). Contaminated sites and initial cleanup activities at LANL were described in this report. A summary of hazardous substances released to the environment at LANL formed the basis for our initial list.

For each of the over 600 solid waste management units (SWMUs) identified in the 1990 Solid Waste Management Units Report, the unit, waste, and releases information sections were reviewed by the project team to identify additional chemicals that may have been released from LANL (LANL 1990).

An additional 480 SWMUs were added by the EPA in 1994, and another 1,000 Potential Release Sites (PRSs) were included in the investigation by the Department of Energy, for a total of 2,120 areas of concern. The 1996 Baseline Environmental Management Report describes historical activities at the potential release sites involving: asbestos, barium, lead, depleted uranium, beryllium, and PCBs (USDOE 1996). High explosives, organic solvents, and ordnance are also cited, but specific chemical names are not provided.

Table 19-3. Reported quantities of chemicals historically used or released at LANL

	CHEMICAL	1971 [1] (kg released)	1972-73 (12 mo.) [2] (kg issued)	1972 [3] (kg used)	1973 [3] (kg used)	1974 [3] (kg used)	1975 [3] (kg used)	1976 [3] (kg used)	1977 [3] (kg used)	1978 [3] (kg used)	1978 [4] (kg losses)	1979 [3] (kg used)	1980 [5] (kg used)	1981 [5,6] (kg used)	1982 [6] (kg used)	1983 [6] (kg used)	1984 [6] (kg used)	1985 [6] (kg used)
	ORGANICS																	
	Methyl chloroform (trichloroethane)	26,571	19,138	25,600	18,300	25,800	22,900	34,000	28,300	24,100	13,741	23,800	28,200	39,300	25,600	31,100	27,674	29,665
C	Trichloroethylene	27,719	17,007	20,400	15,500	16,200	9,400	13,200	10,200	7,400	2,041	6,900	3,400	3,200	390	4,200	2,204	3,041
	Acetone	15,610	--	18,800	9,200	12,400	16,100	15,500	12,700	10,600	2,721	8,300	7,900	10,200	10,700	10,900	10,118	6,735
	Freons	16,825	6,531	10,900	13,300	15,000	10,200	12,400	13,800	8,200	3,265	9,200	12,800	12,500	32,200	28,400	22,006	27,097
C	Perchloroethylene	10,540	680	3,400	680	1,000	820	680	1,000	1,400	--	340	1,400	9,100	340	--	2	32
	Kerosene	7,338	--	8,100	5,000	5,900	4,800	4,600	4,400	3,800	--	4,100	5,800	5,300	5,500	2,800	1,315	614
	Methyl ethyl ketone	--	--	--	--	--	2,300	9,400	10,600	14,300	3,537	22,000	11,400	21,000	400	6,200	5,805	4,238
	Ethanol	--	--	--	--	--	--	1,088	9,200	10,900	--	9,900	9,400	11,800	12,800	13,500	7,024	9,420
	Toluene	2,063	--	2,300	2,100	1,200	2,700	3,300	1,600	2,100	--	2,100	650	60	60	190	337	83
	n-Butyl acetate	--	--	--	--	--	3,311	5,170	2,222	10	--	--	--	--	--	--	--	--
	Ethyl acetate	--	--	--	--	--	--	104	2,404	180	1,633	--	--	--	--	--	--	--
	Methanol	1,125	--	590	540	1,500	1,700	6,600	4,300	2,600	--	3,300	2,400	3,400	3,100	730	3,298	1,607
C	Methylene chloride	1,669	--	820	820	310	1,000	820	2,200	250	771	170	180	230	430	100	1,876	2,028
	Isopropanol	--	--	--	--	--	--	218	952	950	--	--	--	--	--	--	--	--
	n-Hexane	--	--	--	--	--	209	304	290	210	--	--	--	--	--	--	--	--
C	Chloroform	3,088	--	360	250	500	380	370	190	160	--	200	310	250	320	500	177	208
C	Carbon tetrachloride	558	--	300	290	250	100	250	230	200	--	280	100	180	190	60	103	238
	Xylene	--	--	--	--	--	--	86	227	290	--	--	--	--	--	70	59	135
C	Benzene	--	--	181	127	110	45	141	32	40	--	--	--	--	--	70	12	78
	Tetrahydrofuran	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	30	79
C	Dioxane	--	--	--	--	--	--	14	32	15	--	--	--	--	--	--	--	--
	INORGANICS																	
C	Cadmium	1. E-02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C	Beryllium	3. E-05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mercury	--	--	--	--	--	--	500	290	180	--	140	140	200	210	60	24	1
	ACIDS																	
	Nitric acid	20,200	--	--	--	--	--	--	--	80,000	--	58,100	71,900	99,500	70,500	52,100	55,976	54,212
	GASES																	
	Helium	--	--	--	--	--	--	--	--	--	6,800-13,600	--	--	--	--	--	--	--
	Sulfur hexaflouride	6,812	--	17,400	6,700	10,300	11,400	12,200	13,700	9,200	8,209	11,400	6,900	10,600	8,800	14,200	9,507	14,560

-- Not reported.

C known or suspected human carcinogen

[1] 1971 Pollutant Inventory. Releases estimated by group leaders using chemical stock issue records. (Rep. No. 756 / 997).

[2] Response to Sept. 6 TWX Concerning Use of Trichloroethylene. H-5 Division. September 14, 1973. (rep. No. 2816).

[3] Attachment II to Air Quality Regulation Review #3: NAAQS. Chemical and gas usage. June 9, 1980. (Rep. No. 610);
Volatile and/or dangerous chemicals checked out of the storeroom (Rep. No. 1324);
Airborne effluents 1973: airborne releases, nonradioactive 1972-73 (Rep. No. 1197).

[4] Atmospheric Emissions of Non-Radioactive Materials. Losses estimated by LASL groups using >1500 lb/yr. January 17, 1979. (Rep. No. 610).

[5] Attachment I to Nitric Acid and NOx Emissions. November 30, 1982. (Rep. No. 511).

[6] Table G-12, p. 140, of the HSE-8 Annual Report. Attachment to Chlorinated Hydrocarbon Solvents. December 2, 1986. (Rep. No. 280).

The project team has been following Environmental Restoration (ER) activities at LANL since the project began in early 1999. Numerous press releases and fact sheets regarding environmental investigations and surveillance activities have been provided by the ER Project and have supplied some relevant information. Oxalic acid, for example, was used to purify uranium and plutonium in early operations at TA-1 and TA-21. Oxalate has been detected in a groundwater monitoring well in Lower Los Alamos Canyon (LANL 1998b). Recently, perchlorate was detected in a groundwater monitoring well in Mortandad Canyon, in a water supply well in lower Pueblo Canyon, and in the CMR Building ductwork (LANL 2000). Perchloric acid is used in high-explosive (HE) formulation and in nuclear chemistry analyses conducted in CMR Building (Dobratz 1995).

Explosives including HMX, RDX, and TNT that have been detected in a groundwater monitoring well at TA-16 (S Site) and at Material Disposal Area-P reflect machining and subsequent disposal activities that occurred at TA-16, the center for research in high explosives since the 1940s. Prior to constructing the High-Explosives Wastewater Treatment Facility at TA-16 in the 1990s, over 12 million gallons of water per year were used to keep the surface of high explosives cool and wet while machining. Following settling of the solids and heavier materials, the remaining water was discharged to the environment via outfalls. The wet solids were trucked to a burning ground, separated from liquids with a sand filter, then dried and ignited. The filtrate was treated before being discharged. Solvents such as acetone, methanol, and ethanol were released to the atmosphere via volatilization from the water discharged at the outfalls (LANL 1998a, LANL 1999).

Detonable quantities of explosives have been removed from MDA-P during RCRA clean-closure excavation activities (Santa Fe New Mexican 1999). A document located on microfiche in the Central Records Center at LANL states that quantities of explosives burned at TAs-14, 15, 16, 36, and 40 range from 100-300 lb/yr at TAs-14 and 33, to 96,300 lb/yr at TA-16 (Unknown: Central Records Center, Los Alamos National Laboratory). Normal uranium, HE-contaminated solvents (unidentified) and other combustibles are also disposed of by burning at these locations.

Project team review of X-Division Progress Reports from 1944 through 1945 has yielded reported estimates of quantities of high explosives used during that time period. These data are presented in Table 19-4.

Table 19-4. Reported quantities of high explosives used per month (lbs)

DATE>	Aug-44	Sep-44	Oct-44	Nov-44	Dec-44	Jan-45	Feb-45	Mar-45	Apr-45	May-45	Jun-45	Jul-45	Aug-45	Sep-45	Oct-45	Nov-45	Dec-45
EXPLOSIVE																	
Barium Nitrate						3,250	3,170	19,850	42,750	35,000	57,500	60,000	-				18,000
Composition B					23,523	27,600	47,150	80,850									17,000
Composition B-1	6,800	5,366	7,510										-				
Composition B-2			3,900						20,600	87,500	90,250	66,850					
TNT		650	131		1,250	2,935	2,475	7,500	9,200	12,800	20,400	20,150	-				6,000
Aluminum-TNT 60/40					937	1,008	1,390	1,750	200								
Torpex [1]	1,100	1,250	6,953														
Saltex		463															
Pentolite						500	0										
Cyclotol 70/30							250										
PTX										150	100	150					
RDX											6						
Sum	7,900	7,729	18,494		25,710	35,293	54,435	109,950	72,750	135,450	168,256	147,150					41,000
Reported TOTAL	8,900	12,434	18,494	--	23,523	34,793	54,185	109,950	72,550	135,300	168,150	147,000	--	--	--	--	41,000
Waste (lbs)	1,200	1,518	2,160														
Rejected Castings																	28%

Source: X-Division Progress Reports 1944-47 (Rep. Nos. 2931, 2915, 2916, 2917, 2918, 2919, 2920, 2921, 2936, 2935, 3128, 3272, 2937).

[1] Torpex is 5:1 Comp B: TNT

-- Quantities of explosives used are not reported in the monthly X-Division Progress Report for November 1944.

A 1981 memorandum from R. W. Ferenbaugh to H. S. Jordan dated January 27, 1981 states that 20,000 – 30,000 kg (91,000 – 136,000 lbs) per year of waste explosives were disposed of at TA-16 by open burning. Explosive burning experiments conducted at LANL several years prior to 1981 estimated annual emissions of 600-800 kg of NO_x, 100-200 kg of carbon monoxide, and 300-500 kg of unidentified particulates from this open burning process (Ferenbaugh 1981).

An effluent material summary for group GMX-7 includes several explosives dispersed at TA-40 as gaseous detonation products during the period July – September, 1971 (Table 19-5) (Drake, 1971). Toxic material reports for December, 1979 through September, 1980 report the approximate amounts of HE exploded per month in WX-7 shots at TA-40 and TA-22 (Drake, 1971).

Fig. 19-2. LANL workers watch an explosive test in the distance

Table 19-5. Reported quantities of explosives dispersed

Explosive	July – Sept 1971	Dec 1979 (kg)	Jan 1980 (kg)	Feb 1980 (kg)	Mar 1980 (kg)	Apr 1980 (kg)	May 1980 (kg)	June 1980 (kg)	July 1980 (kg)	Aug 1980 (kg)	Sept 1980 (kg)
Nitromethane	450 kg (990 lb)	--	--	--	--	--	--	--	--	--	--
Comp B	34 kg (75 lb)	0.1	3.1	10.8	22.4	13.2	6.7	19.6	--	52.8	9.6
Baratol	--	0.1	2.9	17.1	63.7	21.1	16.4	25	--	89	3.4
TATB	--	0.4	0.7	0.25	0.1	0.4	0.4	0.03	0.6	0.7	0.7
TNT	--	--	--	2.7	5.4	13.5	2.7	5.4	--	25	2.7
Octol	--	--	12	6	3	--	6	3	--	6	--
PETN	7 kg (15 lb)	0.02	0.09	0.06	0.05	0.1	0.01	0.13	0.03	0.05	1.2
PBX	0.9 kg	0.1	0.4	0.4	0.3	0.4	0.3	0.05	0.4	0.3	0.5
Tetryl	0.05 kg	--	--	--	--	--	--	--	--	--	--
TOTAL	492 kg	1	19	37	44	49	32	54	1	174	18

-- not reported

High explosive research, development, and testing was conducted at more than 25 different Technical Areas of LANL (Goldie 1984). Many new formulations of the conventional explosives HMX, RDX and TNT were synthesized and tested at LANL since the 1940s (Dobratz 1995). Other high explosives, such as Baratol, Comp B, Pentolite, Torpex, and Tetryl were tested at the firing site at TA-14 (IT Corporation 1989).

Uranium and other metals, such as lead, beryllium, aluminum and cadmium, were released to the environment as a result of test shots conducted at LANL since the 1940s (Johnson and Dahl 1977, Zenzen 1993). Drake and Eyster (1971) estimate that between 75,000 and 95,000 kg of uranium has been expended in experimental shots at LANL from 1949-1970 (Drake and Eyster 1971). Normal uranium was used until 1954, and then depleted uranium was used exclusively. The estimate does not address where the uranium went, only that LANL no longer has it. A 1952 AEC report states that test shots at LANL routinely dispersed 300 lbs of uranium per month and 2000 lbs of barium per month (English S.G. 1952). Two 1971 memoranda report toxic materials dispersed by GMX Division shots for April and May, 1971 as shown in Table 19-6 (Drake 1971).

Table 19-6. Materials dispersed by GMX Division shots for April and May 1971

Toxic Material	April 1971	May 1971
Uranium 238	171 kg (376 lb)	142 kg (312 lb)
Beryllium	0.7 kg	3 kg
Tritium	125 cm^3 STP	208 cm^3 STP
Lead	0.042 kg	0.8 kg
Bromine	0.165 kg	--

-- not reported

Most of the documents describing PCBs at LANL identified by the project team to date are logbooks of analytical results with unidentified sampling locations. Several documents describe storing and disposing PCB wastes at TAs-21 and 54 (Santa Fe Engineering 1995). PCB cleanups were conducted at TAs-3, 53, and near groundwater production wells in the mid 1980s and 1990s as a result of leaking transformers and capacitors (LANL 1993a, Unknown: PCB Cleanup at TA-3 (OU 1114), 1995-1997). Aroclor-1242 was used as a coolant in CMB-11 division in 1961 (Enders 1969).

A 1973 document, "Summary of wastes and effluents for Omega Site TA-2", estimates that 1.4 lb d^{-1} of hexavalent chromium were released to the air in cooling tower effluent. The Omega West Reactor (OWR) primary water was cooled via a 5 MW evaporative cooling tower. Trichloro-s-triazinetrione ($C_3N_3O_3Cl_3$), a common microbicide, was added to the secondary-side water in the tower to control algae growth. A second product containing polyacrylate polymer, polyoxylated aliphatic diamine, and tolyltriazole was added to control scale and corrosion. Cooling tower water was discharged to the environment via entrainment in the exhaust air stream and through discharges of blowdown water to Los Alamos Canyon Creek. These blowdown discharges were another measure used to control scale and corrosion in the secondary (sump) water by eliminating solids. (LASL 1973b) reports that these discharges totaled approximately 60,000 gallons per week in 1973. Another 300 gallons per week of blowdown water came from the heat exchanger for the primary water in the OWR's demineralizer loop. Like the main OWR exchanger, the cooling water for this heat exchanger came from the municipal water supply.

The same 1973 LASL document also reports the exhaust air stream from the OWR cooling tower included entrained secondary water that was discharged to the environment at a rate of 3.9 gal min^{-1} (LASL 1973b). The document states that this discharge resulted in 20 lb of sulfuric acid and 1.4 lb of hexavalent chromium being released into the atmosphere per 24 h period.

Draft Comprehensive Environmental Assessment and Response Program (CEARP) documents from 1986 (LANL 1993b) report a staff member who recalled using potassium dichromate in the cooling tower water prior to a time when the heat exchanger components were changed from aluminum to steel. CEARP was the Department of Energy's Superfund program for Federal Facilities in the 1980s. The employee stated that mist from the tower would drift through the site, turning things green. This "greening" effect disappeared with the switch to steel components (and the subsequent reduction potassium dichromate use). Using potassium dichromate as a corrosion inhibitor is confirmed in Repos. No. 645, which states that the blowdown discharges from the cooling tower (~60,000 gal per week) included approximately 14.5 pounds of hexavalent chromium (LASL 1973b). This same document reports that the blowdown also included 3 lb of chlorophenol biocide and 200 lb of sulfuric acid in the form of sulfate salts (used for pH control). The blowdown from the demineralizer loop heat exchanger contributed another 20 lb of sulfuric acid and 0.5 lb of chlorophenol biocide. Repos. No. 645 also indicates that a switch from aluminum to stainless steel components in fiscal year 1974 was planned in order to reduce the amount of corrosion inhibitor required, and thereby reduce the amount of hexavalent chromium in the blowdown water (LASL 1973b).

An inventory of pollutant releases to the environment for 1971 (LASL 1971) states that use of chromates will be discontinued once the aluminum heat exchanger is replaced with a stainless steel unit. This same document reports the average concentration of hexavalent chromium in the TA-2 blowdown to be 25 mg L^{-1}, which was 2,500 times the quality standard of 0.01 mg L^{-1} for that era. The same effluent stream reportedly contained total dissolved solids at an average concentration of 800 mg/l, which also exceeded the applicable quality standard of 500 mg L^{-1}.

The Water Boiler's cooling tower used potassium dichromate by the hundreds of pounds; waterborne effluent ran down the nearby creek, and sometimes chromium "rained from the sky," and car windshields had to be replaced (Personal communication, G. Neely, 1999). Condensate poured on the ground, resulting in a tree in the area with Cs-137 in its leaves. Asbestos in some TA-2 buildings was also reported.

Repos. No. 2211 reports that a "very serious" mercury spill took place at the Clementine site on December 31, 1948 that required a "prolonged period" of cleanup (LANL 1949). This report also mentions that routine monitoring for mercury vapor had been on-going at the Clementine site prior to this incident.

Repos. No. 2201 reports that a mercury spill occurred at the Clementine site between January 20, 1951 and February 20, 1951 (LANL 1951). Air samples were collected and analyzed for mercury vapor, and urine samples were collected from three exposed workers. The report states that "the results obtained showed all exposures below hazardous levels."

In late 1952, members of H Division participated in conferences regarding the large quantity of contaminated mercury to be pumped from the fast reactor at Omega Site. Since the material was contaminated with plutonium, participants thought that the plutonium hazard was more serious than the mercury vapor (Shipman 1953).

Perchlorate was identified in shallow groundwater in Mortandad Canyon at concentrations ranging from 80 to 220 ppb. Perchlorate was also found in groundwater characterization wells at 12 ppb, and in drinking water supply wells at two to three ppb, just above analytical detection limits. The perchlorate contamination was assumed to have been discharged in effluent from the TA-50 Radioactive Liquid Waste Treatment Facility, and also from legacy waste that was discharged into Acid Canyon from the TA-45 treatment plant, which operated from 1943 to 1964.

In August 2002, benzene was identified in soil at TA-48 from historical solvent use.

Accident/ incident files from the Health Divisions were identified for 1944-1991 (Repos. Nos. 3461-3496). However, the files primarily document chemical spills and indoor exposures to workers. Operations related to the presence of the chemical are not described. The documentation of a few incidents that could have resulted in releases to the off-site environment was extracted and entered into the project database. A document titled "Chronological Record of Accidents at LASL" lists a fatality due to asphyxiation by methyl chloroform at "New" Sigma Building on February 14, 1961 (Unknown 1979). Details of the accident are not provided.

Many of the Health/ Industrial Hygiene Division reports and correspondence files include memoranda regarding the presence of numerous solvents, metals, and acids in various LANL divisions. Details regarding building locations, quantities used, or the operations involved, however, are rarely provided. The chemicals mentioned are included in Table 13-1.

Preliminary Prioritization for Chemicals

USEPA Region 9 Preliminary Remediation Goals (PRGs) are target cleanup levels based on conservative assumptions regarding direct exposure to soil through ingestion, dermal contact and inhalation, and direct vapor and particulate inhalation (USEPA 2002). PRGs are based on cancer as an endpoint if available

cancer potency factors ("slope factors") result in a more conservative (lower) PRG than would result based solely on evaluating non-cancer health effects.

As a first step towards prioritizing potential chemical releases, PRGs for chemicals used, and possibly released historically from LANL, were used by the LAHDRA team to rank the potential of various chemicals to result in adverse health effects to off-site populations. The lower a PRG, the higher the potential for off-site health effects if the compound were released beyond the site boundary. This preliminary ranking does not address actual quantities released or whether real exposures occurred; however, these factors will be considered if the prioritization process advances.

PRGs for soil were used to rank chemicals usually present in the environment as particulates, and PRGs for air were used to rank volatile chemicals. Both soil and air PRGs were considered for explosives. Toxicity factors are not available for some chemicals used at LANL, and estimates of quantities used have been identified through systematic document review for only a subset of those chemicals with published toxicity factors. Estimates of quantities of a material used on an annual basis are available in some cases. "Annual use" is typically the highest known annual usage of a compound from available data, and, in some cases, may be based on a single year for which data are available. Reported values are often presented as quantities used, issued, lost, or released, and it is not always clear how the quantities were determined.

Table 19-7 shows a ranking of LANL chemicals based on PRGs for soil, while Table 19-8 presents a ranking based on PRGs for air. Table 19-9 presents a ranking method that takes into account estimates of annual usage and U.S. EPA toxicity values, such as slope factors and RfDs. Oral slope factors are used to indicate the strength of the chemical's ability to cause cancer. A cancer slope factor is an upper bound probability estimate of cancer incidence per unit intake of a carcinogen over a lifetime. The higher the slope factor, then, the more carcinogenic a chemical is, according to the U.S. EPA. RfDs are used to rank a chemical's ability to cause an adverse health effect other than cancer. According to the U.S. EPA, an RfD is an estimated daily intake that, if taken over a lifetime, is not expected to cause an appreciable risk of adverse health effects. Hence, according to the U.S. EPA, the smaller the RfD, the more toxic the chemical. Chemicals were ranked based on slope factors and RfDs independently to distinguish between the most important chemicals in terms of cancer risk and adverse health effects. Chemicals that are considered carcinogens by the U.S. EPA were ranked based on annual usage multiplied by the cancer slope factor. Oral slope factors were used in all but one case because they are more conservative than the inhalation slope factor. All chemicals for which the U.S. EPA has published RfDs were ranked by multiplying the annual usage by the inverse of the RfD. Some chemicals have both ingestion and

inhalation RfDs, and, in these cases, the more conservative value was used in order to consider the most sensitive health endpoint.

Table 19-7. Ranking of LANL chemicals based on PRGs for soil

Chemical	PRG for Soil (mg/kg)	Rank
Arsenic	3.90E-01	1
RDX (hexahydro)	4.40E+00	2
Thallium	5.20E+00	3
Perchlorate	7.80E+00	4
TNT (2,4,6-trinitrotoluene)	1.60E+01	5
Uranium	1.60E+01	6
Nitrobenzene	2.00E+01	7
Mercury	2.30E+01	8
Antimony	3.10E+01	9
Vanadium	7.80E+01	10
Molybdenum	3.90E+02	11
Silver	3.90E+02	12
Lead	4.00E+02	13
Lithium	1.60E+03	14
Nickel (soluble salts)	1.60E+03	15
Manganese	1.80E+03	16
HMX (octahydro)	3.10E+03	17
Copper	3.10E+03	18
Fluoride	3.70E+03	19
Barium nitrate	5.40E+03	20
NQ (nitroguanidine; Picrite)	6.10E+03	21
Acetone	1.40E+04	22
Iron	2.30E+04	23
Zinc	2.30E+04	24
Aluminum	7.60E+04	25
Bromine	N/A	
Gallium	N/A	
Lanthanum	N/A	
Niobium	N/A	
Platinum	N/A	
Samarium	N/A	
Tantalum	N/A	
Zirconium	N/A	

Table 19-8. Ranking of LANL chemicals based on PRGs for air

Chemical	PRG for air [microgram/m^3]	Rank
Chromium (total)	1.60E-04	1
Beryllium	8.00E-04	2
Cadmium	1.10E-03	3
Polychlorinated biphenyls- Aroclor 1242 (1254)	3.43E-03	4
Trichloroethylene	1.70E-02	5
Chloroform	8.30E-02	6
Hexachlorobutadiene	8.60E-02	7
Carbon tetrachloride	1.30E-01	8
Benzene	2.50E-01	9
Tetrachloroethylene	3.20E-01	10
1,4-Dioxane	6.10E-01	11
Tetrahydrofuran	9.90E-01	12
Hydrogen Cyanide	3.10E+00	13
Methylene chloride	4.10E+00	14
Phosphoric acid	1.00E+01	15
Chloromethane	9.50E+01	16
Xylene	1.10E+02	17
Dichlorodifluoromethane	2.10E+02	18
n-Hexane	2.10E+02	19
Toluene	4.00E+02	20
Ethyl Ether	7.30E+02	21
Methanol	1.80E+03	22
Trichloroethane (methyl chloroform)	2.30E+03	23
Ethyl acetate	3.30E+03	24
Methyl ethyl ketone	5.10E+03	25
Ethylene glycol	7.30E+03	26
1,1-Difluoroethane	4.20E+04	27
Chlorodifluoromethane	5.10E+04	28
Naphthalene	N/A	
Ethanol	N/A	
Isopropanol	N/A	
Kerosene	N/A	
Tetrabromoethane	N/A	
n-Butyl acetate	N/A	
Asbestos (magnesium silicate)	N/A	
Bromide	N/A	
Hydrochloric acid	N/A	
Hydrofluoric acid	N/A	
Nitric acid	N/A	
Oxalic acid	N/A	
Sodium hydroxide	N/A	
Sodium thiosulfate	N/A	
Sulfur hexafluoride	N/A	
Sulfuric acid	N/A	
Baratol (barium nitrate+TNT)	N/A	
Comp B (60% RDX; 40% TNT)	N/A	
Cyclotol (70-75% RDX; 25-30% TNT)	N/A	
Explosive D (NH3 picrate; NH3-1,3,5-trinitrophenol)	N/A	
Nitrocellulose	N/A	
Nitromethane	N/A	
Octol (70-75% HMX; 25-30% TNT)	N/A	
PBX	N/A	
Pentolite	N/A	
PETN (pentaerythritol tetranitrate)	N/A	
Picric acid	N/A	
PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine)	N/A	
Saltex	N/A	
TATB (1,3,5-triamino-2,4,6-trinitrobenzene)	N/A	
Tetryl (1,3,5-trinitrophenyl-methylnitramine)	N/A	
Torpex (83% Comp B; 17% TNT)	N/A	

Table 19-9. Ranking of LANL chemicals based on toxicity parameter and annual usage[1]

Chemical	Slope Factor (SF) [mg/kg-d]$^{-1}$	Reference Dose (RfD) [mg/kg-d]	Annual Use [kg]	Ranked Based on Cancer Effects		Ranked Based on Non-cancer Effects	
				SF x Annual Use	Rank	1/RfD x Annual Use	Rank
Acetone	-	0.9	18,800	-		20,889	13
Barium nitrate	not in RAIS	not in RAIS	108,873	-		-	
Benzene	0.055	0.004	181	10	7	45,250	9
Carbon tetrachloride	0.13	0.0007	558	73	5	797,143	5
Chlorodifluoromethane[2]	-	14.3	32,200	-		2,252	17
Chloroform[3]	0.0805	0.01	3,088	249	4	308,800	7
Dichlorodifluoromethane[2]	-	0.0571	32,200	-		563,923	6
Dioxane	0.011	-	32	0.35	8	-	
Methanol	-	0.5	6,600	-		13,200	14
Methyl ethyl ketone	-	0.6	22,000	-		36,667	12
Methylene chloride	0.008	0.06	2,200	17	6	36,667	11
n-Hexane	-	0.06	304	-		5,067	16
Tetrachloroethylene	0.54	0.01	10,540	5,692	2	1,054,000	4
Tetrahydrofuran	not in RAIS	not in RAIS	79	-		-	
TNT (2,4,6-trinitrotoluene)	0.03	0.0005	37,950	1,139	3	75,900,909	3
Toluene	-	0.08	3,300	-		41,250	10
(chloroform)	-	0.2	39,300	-		16,500	8
Trichloroethylene	0.4	0.0003	27,719	11,088	1	92,396,667	1
Uranium	-	0.0006	47,500	-		79,166,667	2
Xylene[2,4]	-	0.0286	290	-		10,140	15

[1] All values were obtained from the Risk Assessment Information System (RAIS) available at: http://rais.ornl.gov

[2] Inhalation RfD was used because it was more conservative than the oral RfD. In all other cases, oral RfDs were used because they were most conservative

[3] Inhalation cancer slope factor was used because it was more conservative than the oral slope factor. In all other cases, oral slope factors were used because they were most conservative

[4] Combined congener values were used (combined, p-, m-, o-).

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Chapter 20: A Screening-Level Evaluation of Airborne Beryllium Releases from LANL Operations

Introduction

Historical records indicate that beryllium was used at LANL for some time before its health hazards were fully recognized (Shipman, 1951, Hempelmann and Henrickson, 1986). While beryllium has become recognized as a worker health hazard, potential exposures to Los Alamos residents have not been as well characterized. Because residents lived closer to LANL production and testing areas than at any other nuclear weapons complex site, this screening-level assessment of potential public exposures was undertaken**.**

Identification of Sources of Beryllium Releases at LANL

Based upon the review of information collected under the LAHDRA project, screening level assessments were completed for the following historical operations at LANL involving processing or using significant quantities of beryllium:

- Early machining operations at a shop in the Original Technical Area (TA-1), known as V-Shop;
- Machining in shops at TA-3, Building SM-39, that started late in 1953;
- Testing atomic bomb components by firing them from a 20-mm anti-aircraft autocannon in an annex to B Building at TA-1;
- Hot pressing of beryllium oxide powder in Q Building at TA-1 to make reactor components; and
- Expending beryllium in explosive tests conducted at the PHERMEX facility at TA-15.

Estimation of Release Rates over Averaging Periods Shorter Than a Year

Limits on occupational and public exposures to beryllium are stated as concentrations that vary with averaging time, including those specified for instantaneous concentrations, as well as eight hour and 30 day average concentrations. Generally, the shorter the exposure (or stack sampling) time, the higher the allowed concentration. However, reported LANL beryllium air concentrations are often reported or estimated in terms of annual averages or totals released over a year. During any year, concentrations over short periods will be greater than (and, at other times, also less than) the annual average. Because there is evidence suggesting that the occurrence of chronic beryllium disease is not related to exposure duration (ATSDR, 2002), indicating that exposures over short periods can be of health significance, the LAHDRA

team recognized the need for a method to predict the upper bounds of airborne beryllium concentrations over time intervals from less than an hour to 30 days based on data that represent concentrations or releases over a full year.

In order to estimate the magnitude of airborne concentration variations that would be expected within a year, we looked at another material released in particulate form by LANL: plutonium. As was the case with beryllium, facilities that exhaust plutonium to the air have been subject to increasingly stringent controls, resulting in using filters on exhausts in the 1950s and high efficiency particulate air (HEPA) filters by the mid-1960 for both contaminants. Samples of the exhaust air from plutonium facilities at LANL have also been collected on filters to assess effluent air concentrations. Further discussion of similarities between plutonium and beryllium particles, how they behave, and how they have been assessed by others, is provided elsewhere (Shonka, 2009). Unlike beryllium, however, plutonium samples have been routinely reported for time intervals as short as one work day.

In order to estimate how high beryllium release rates from chronic release sources could have been over averaging periods shorter than a year, the LAHDRA team analyzed the detailed monitoring data available for airborne plutonium releases from DP West Site stacks for 1956 and 1957. The relationships between work-day averaged concentrations and weekly, monthly, and annual average concentrations were characterized, and a table of multipliers was generated that could be applied to annual data to estimate peak releases over a series of shorter durations. To support this preliminary screening, airborne beryllium releases were assumed to vary over time, similar to the measured airborne plutonium releases (that is, having similar ratios of annual averages to averages over shorter periods), and estimated annual beryllium releases were converted to release rates over shorter durations so that airborne concentrations over appropriate averaging periods could be compared to occupational and ambient exposure limits. If historical beryllium operations and releases are further evaluated, a more detailed analysis of operational and air sampling data for beryllium activities might support a more direct characterization of the temporal variations of beryllium concentrations in exhaust streams.

Nine-hour averaged air concentrations of plutonium (corresponding to weekday working hours) for the four main stacks on Building 12 at DP West Site for calendar years 1956 and 1957 were entered into a spreadsheet. Raw daily data have not been located for earlier years. HEPA filters were added to the process exhaust system at DP West in 1959, and, because the bulk of the releases from the facility appear to have come from exhausts that were not HEPA filtered, the earlier data was chosen as most representative of the conditions of greatest interest.

Averages were computed for nine h (the raw data) as well as for weekly (45 h), monthly (196 h), and annual (2,349 h) averages. The data were maintained as nine hour working days in order to match the recorded data. In addition, the actual days for each week and month within 1956 and 1957 were maintained. Except for the annual average data, which had only one data point for each series (1956 and 1957), the data for each averaging period were fit to lognormal distributions with excellent residuals.

A lognormal distribution can be fitted to an equation of the form $y = a \times e^{bx}$, where 'y' is the natural log of the observed concentration, and 'x' is the standard deviation. The exponential constant (e^b in the equation $y = a \times e^{bx}$) provides the geometric standard deviation of the lognormal distribution. Both 1956 and 1957 had similar exponential factors, and the data were averaged for a best estimate. Data examination indicated no general time dependence in concentration over the course of a year (such as slow falloff with time), even though LANL emissions did trend lower over the decades of DP West operations. The "b" value was plotted as a function of the log of the integration time and fit to a linear equation. Using this equation, the geometric standard deviations (e^b) for treated particulate releases were predicted for various integration times ranging from six minutes to one month.

The analyses of the releases from DP West are summarized in Table 20-1 below. The 95th percentile for monthly data would correspond (roughly) to a concentration reached on one day of each month. As shorter time intervals are used, the 95th percentile is reached more and more often, and so is not a useful factor for use in a conservative analysis. For example, using the 95th percentile, the 1-h data would be expected to either be larger or smaller than the annual average by a factor of 8.2 for one hour out of every 20. Thus, hourly data would expect to be exceeded every one or three days, and six minute (0.1 h) data would be seen as often as twice a day. As a result, the table also lists the multiplicative factor that would be found for a concentration that would be attained once per 1600-h work year. By using the "once per year" values, Table 20-1 shows that the one hour data would exceed the annual average values by a factor of 30 for the estimated highest hour of the 1600 hour work year. Although the regulatory requirements dictate an instantaneous limit, this analysis has limited the averaging period to a minimum of 0.1 h. The data indicate that at 30 min of sampling or exposure time (0.5 h), the concentration would exceed annual averages by a factor of 47 once per year. No "once per year" multipliers are provided for weekly or monthly time periods; the 95th percentile should be used for screening for those time periods. The duration factors are not used in estimating episodic releases, for which releases for each event were estimated and converted to average concentrations over longer periods based on assumed numbers of events of stated material content within each period.

Table 20-1. Geometric standard deviation data based on analysis of detailed DP West plutonium stack sampling data, with factors to estimate release rates over periods shorter than one year

			Multiplicative factors to be applied to annual values to estimate values over specified intervals	
Time Interval	**Equivalent Hours**	**"b" Value [a]**	**95th Percentile**	**Once per year**
6 min	0.1	1.3	13.6	149
30 min	0.5	1.1	9.5	47
Hour	1	1.1	8.2	30
Work Day	8	0.8	5.2	8.3
Day	24	0.7	4.1	4.6
Work Week	40	0.6	3.6	
Week	168	0.5	2.7	
Month	730	0.3	1.9	
Work Year	1,600	0.2	1.6	
Year	8,760	0	1	

[a] The term e^b represents the geometric standard deviation of the lognormal distribution fitted to DP West stack sample analysis results.

Estimation of Beryllium Release Rates for Identified Emission Sources

Fabrication of components from beryllium metal and oxide (TA-1 and TA-3)

a) New Beryllium Shop (TA-3, South Mesa Building 39, "SM-39," Beryllium Shop 4)

South Mesa Building 39, "SM-39," Beryllium Shop 4 was outfitted with a HEPA filter on the exhaust in 1964. Release measurements after this time period were found for six years in the 1960s, and were reported in a manner that permits annual average releases to be computed. The study of DP West stack particulate releases of plutonium, discussed earlier, provide a means to estimate the concentrations for shorter time periods. The exhaust system apparently ran only during normal working hours, but it is unclear if the stack sampler pump was only operated when the stack exhaust fan was operating. This assessment assumes that the sampler pump also only ran during the hours of operation. If it did not, then the "sampler hours of operation" correction would provide an additional factor of 5.5 increase for the total beryllium released, (= 8760 h / 1600 h), since the concentration in the stack would be expected to be much lower when the machining operations ceased during non-working hours. The documentation of the data for 1964 through 1966 did not identify fan hours of operation, so the average of the operating hours (1600) for the 1968 through 1970 period was chosen.

Table 20-2 and Table 20-3 below summarize the release data found (LASL, 1969, 1970). Table 20-3 has the duration factors from Table 20-1 for each time interval applied to the data from 1970 to permit comparison with applicable limits. The screening calculations utilize 1970, the highest year that has been found to date.

The annual release rate for 1600 h (0.0245 μg s^{-1} for 1970) must be adjusted by 1600 h /8760 h to correctly express the average release rate in a year. In Table 20-2, the "Working Hours" column refers to the fan operating time, which is also the operational release period. The Mass Released column is the release for the specified year. The stack flow rate was 2,000 ft^3 min^{-1} (LASL, 1970).

In Table 20-3, the time periods of one day or longer have been corrected for the fact that the release occurs over a shorter time than the integration period. For example, the year release rate is 0.0245 μg s^{-1} times 1602.6 h of operation divided by 8760 h y^{-1}. For time periods less than the operating period (i.e., one hour or less), this factor is no longer applied, since the six to nine hour workday was longer than those time periods, so there is no need to correct for the time the stack exhaust was not operating.

The work day time period corresponds to an eight hour day, the work week to a 40 h period, the month to a 730 h period, and the year to 8760 h. These time amounts were chosen in order to permit comparison to occupational and ambient exposure limits.

Table 20-2. Measured beryllium releases from SM-39 shop at TA-3 after 1963

Year	Working Hours	Mass Released, g	Working Hours Release Rate, μg s^{-1}
1964	1600	0.0105	0.0018
1965	1600	0.0106	0.0018
1966	1600	0.0188	0.0033
1967	No data found		
1968	1545.7	0.0089	0.0016
1969	1687.7	0.0378	0.0062
1970	1602.6	0.1416	0.0245

Table 20-3. Estimated SM-39 beryllium shop release rates after 1963 based on measurements made in 1970 and application of duration factors

	Release Rate for Stated Averaging Period, μg s^{-1}						
Year	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1970	3.65	1.16	0.73	0.20	0.089	0.0086	0.0045

b) TA-3, SM-39 Beryllium Shop Operations 1953 - 1963

The beryllium shop at SM-39 began operating in 1953 as a replacement for the inadequate facilities in the main shop at V-Building in the Original Technical Area. At the start of operations, no provisions were made for HEPA filtration of exhausts. Release measurements were not found for the SM-39 shop in this era. In order to estimate a lower bound for air concentrations and releases from the SM-39 beryllium shop from 1953 to 1963, measurements from the late 1960s were adjusted to account for the fact that no HEPA filters were in place. In general, HEPA filters are assumed to attain a filtering efficiency of 99.97% (USDOE, 2003). This figure corresponds to a reduction of the effluent by a factor of 3,333 (=1/ (1-0.9997)). This efficiency is obtained at a particle size diameter of 0.3 μm in diameter, with better efficiencies realized for smaller and larger particles. Data indicate that the filter systems used during this era attained efficiencies in the 90% range. An assumed 95% efficiency would attain reduction by a factor of 20. The ratio of the pre- and post-1964 filter reduction factors is 167 (=3,333/20). For this assessment, SM-39 exhaust monitoring data from 1970 were multiplied by 167 to estimate release rates for 1953 through 1963 (see Table 20-4). Use of this factor likely understates the releases by a considerable amount, given that the airborne particles larger or smaller than 0.3 micron diameter would have been filtered more efficiently. A partially offsetting factor for this conservatism may come from the fact that an improperly installed HEPA filter may not have attained 99.97% efficiency. Because the values represent long term averages, they were multiplied by the factors in Table 20-1 for the desired sampling or exposure time to provide the data in Table 20-5. For comparison purposes, the 1970 data that were the basis for 1953-1964 are repeated in Table 20-5. The 1,600 h y^{-1} exhaust operating period was also assumed. The impact of the lack of HEPA filters before 1964 can readily seen in Table 20-5 by comparing the 1953–1963 data with the 1970 values.

Table 20-4. Estimated airborne releases from the SM-39 beryllium shop from 1953 to 1963

Year	Working Hours	Annual Average Concentration, μg m^{-3}	Mass Released, g	Working Hours Release Rate, μg s^{-1}
1953 – 1963	1600	4	24	4
1970	1602.6	0.0260	0.1416	0.0245

Table 20-5. Estimated SM-39 beryllium shop release rates for 1953–1963 based on measurements in 1970, correction for non-HEPA filtration, and application of duration factors

	Release Rate for Stated Averaging Period, μg s^{-1}						
Year	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1953-1963	610	194	122	34	15	1.4	0.7
1970	3.65	1.16	0.73	0.020	0.089	0.0086	0.0045

c) V-Building Shop Operations at TA-1 between 1949 and 1953

The main shops in V-Building at the TA-1 were used for machining beryllium prior to the startup of the SM-39 shop at TA-3 in 1953. Around late 1948, when LANL was informed of beryllium's hazardous nature, the high speed machining operations were relocated into an annex to V-Building, and an exhaust system was added with filters. For the purposes of this analysis, it was assumed that the non-HEPA filters that were used had comparable filtering efficiencies to the filtering system used at the SM-39 shop at TA-3 before HEPA filtration was added. Because the operations in the V-Building shop appear to have been grossly similar to those at the SM-39 shop, the estimated release rate for the SM-39 shop for 1953-1963 was used for V- Building shop from 1949 to 1953. The main difference between the two emission sources in terms of prioritization will be the shorter separation of V-Building from nearby residences. Estimated beryllium releases are summarized in Table 20-6 and applied to various averaging periods in Table 20-7.

Table 20-6. Estimated airborne releases from the V-Building shop at TA-1 from 1949 to 1953

Year	Working Hours	Annual Average Concentration, μg m^{-3}	Mass Released, g	Working Hours Release Rate, μg s^{-1}
1949 – 1953	1600	4	24	4

Table 20-7. Estimated V-Building beryllium shop release rates for 1949 through 1953 with duration factors applied

	Release Rate for Stated Averaging Period, μg s^{-1}						
Year	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1953-1963	610	194	122	34	15	1.4	0.7

d) V-Building Shop Operations at TA-1 between 1943 and 1948

At the start of LANL operations, the main shops in V-Building at TA-1 were used for machining beryllium. Prior to around 1948, when LANL was informed of beryllium's hazardous nature, the operations occurred in the shop itself with no specialized exhaust ventilation. Because the nature of the operations at the V-Building shop appear to have been grossly similar to the SM-39 shops at TA-3, using that release rate estimate is appropriate. However, the releases were not collected by a process exhaust system, and were not released through a stack. We assume that the releases occurred from the normal ventilation of the shop area, perhaps from a ventilation fan. In contrast to the case of the post-1949 V-shop operations, the main change in prioritization will be the diffuse release through building ventilation, as opposed to a stack. As in the case of the V-Building shops 1949 - 1953, because the nature of the operations was grossly similar to the TA-3 shops, using the release rate estimate for the SM-39 shop 1953-1963 is appropriate. As for all sources of chronic releases, the Table 20-1 factors were applied to correct the annual average to the sampling or exposure time of interest. Estimated beryllium releases are summarized in Table 20-8 and applied to various averaging periods in Table 20-9.

Table 20-8. Estimated airborne releases from the V-Building shop at TA-1 from 1943 to 1948

Year	Working Hours	Annual Average Concentration, μg m^{-3}	Mass Released, g	Working Hours Release Rate, μg s^{-1}
1943–1948	1600	87	472	82

Table 20-9. Estimated V-Building beryllium shop release rates for 1943 through 1948 with duration factors applied

	Release Rate for Stated Averaging Period, μg s^{-1}						
Year	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1943–1948	12,156	3,859	2,427	679	297	29	15

Gun testing of atomic bomb initiators containing beryllium– B-Building Annex at TA-1

In order to estimate beryllium releases from gun testing of atomic bomb initiators, it was assumed that each of the daily initiator tests used 566 g (the mass of a metal sphere of beryllium of 10 mm radius; based on 20-mm barrel diameter of the gun at B-Building), and an estimated 10% was aerosolized and exhausted from the room, or 57 g per test. Documents that describe initiator testing have a data block that lists typical values of 90 to 120 "Gr" projectile weights. This mass is close to the mass of a normal

projectile the auto-cannon would fire, and would be consistent with grams rather than grains. If the projectile weight was in grains, only eight grams would be used for the entire projectile, which seems too low in mass to be realistic. Using the stated mass of the projectile would mean that the beryllium released would be five times less that stated earlier (solid sphere of beryllium of 20 mm diameter) for each shot. For this initial assessment, 120 g is assumed to be expended, of which 10% was released. During the first 180 days of the program, 180 initiator tests were conducted. That being the case, it appears that the B-Building Annex alone released more than 2160 g (10% of 120 g for 180 tests) over the one half year in 1944 for which data were found. This total release would amount to 4,320 g y^{-1}.

After each test was fired, the 10% fraction assumed to be aerosolized was dispersed into the room and removed by the ventilation system. It was assumed that a flow rate sufficient to produce 12 air changes per hour was used. If the beryllium was uniformly mixed into the room volume, the concentration would drop exponentially with a time period equal to the inverse of the ventilation rate. A time sufficient to produce two air changes (0.1 h or six min) would remove most of the beryllium, and was assumed to be the release period. Thus, the release would correspond to 12 g of beryllium over 360 s, or 0.033 g s^{-1}. The data sheets reviewed indicate test frequency of roughly once per day. Thus, a test was assumed to occur 365 days per year. Because the release rate considers the release time, the duration factors of Table 20-1 are not applied for these episodic releases. With a release each day (365 d y^{-1}) and duration of 0.1 h, the release is assumed to occur over a 36.5-h operating period. However, the release rate when averaged over longer periods of time drops with the ratio of the averaging period to that of the considered duration of release. No annual average concentration is provided. The hours of operation of what is believed to have been a nominal 600 ft^3 min^{-1} ventilation fan are not known. Estimated beryllium releases are summarized in Table 20-10 and applied to various averaging periods in Table 20-11.

Table 20-10. Estimated airborne beryllium releases from B-Building gun testing at TA-1, 1944–1948

Years	Operating Period, h	Mass Released, g	Release Rate, µg s^{-1}
1943–1948	36.5	4,320	33,333

Table 20-11. Estimated beryllium release rates from B-Building gun testing (duration factors not applied)

	Release Rate for Stated Averaging Period, µg s^{-1}						
Years	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1943–1948	33,333	6,667	3,333	417	417	139	139

Explosive testing of bomb components containing beryllium

During the peak year of dynamic testing, 1964, a total of 106 kg of beryllium was used at TA-15, a fraction of which was aerosolized into fine particulate form that would distribute downwind. While LANL has traditionally assumed 2% of the mass is aerosolized, this assumption (along with others) fails to account for the mass of beryllium expended at the firing sites and found in nearby soils. Lawrence Livermore National Laboratory (LLNL) has assumed that 8% of the mass is aerosolized. Both of those values (either 2% or 8%) resulted from experiments conducted by the laboratories. Finally, the Dual-Axis Radiographic Hydrodynamics Test (DARHT) facility, EIS, which was published more recently, assumed a value of 10%. For this analysis, it was assumed that 10% of the 106 kg expended in 1964 was aerosolized.

The amount of beryllium used in a specific experiment is classified. In order to estimate a release rate, it was assumed that between 50 and 150 experiments were performed at the three firing sites during the year (less than once per week), with a total of 100 experiments performed. It was assumed that 80% of the experiments did not use beryllium at all, and, of the 20 experiments that did, 16 used small amounts of beryllium (together accounting for 50% of the total mass) and four of them used larger amounts (together accounting for 50% of the total mass). Each of the larger experiments might have used 13.25 kg.

The duration of the exposure from the explosive test was taken to be 0.25 h as the puff drifted off-site with the prevailing wind. This heuristic estimate is based partially on the estimated size of the puff a short time after detonation, as well as subsequent dispersion of that puff as it drifted approximately 5,000 m off site with an average wind speed.

Because the release rate considers the release time, the factors of Table 20-1 are not needed. Table 20-12 provides the annual average values (10% of 106 kg dispersed in 0.25 h × 100 tests = 25 h), as well as the peak (one of four tests in the year that dispersed 10% of 13.25 kg in 0.25 h). Table 20-13 applies the peak rate to time intervals of a week or less, and assumes the annual release rate for the year and the month. Assuming that one of the shots that month used 13.25 kg (and the rest averaged the 1.06 kg), then the month would be a factor of 2.3 times larger. This factor was not used in order to maintain a simpler set of assumptions. Using this method provides an average rate for the month equal to the annual rate. In fact, it is likely that the month in which a larger-than- average quantity of beryllium was used in shots had higher release rates than 336 $\mu g\ s^{-1}$ over the 730 h period. These higher releases could be confirmed if beryllium release assessment continues, and if detailed (classified) shot records are retrieved and summarized in a manner that could be publicly releasable.

Table 20-12. Estimated airborne beryllium releases from TA-15 explosive testing

Year	Duration of Exposure, h	Mass Released, g	Release Rate, μg s^{-1}
1964 (year)	25	10,600	117,778
1965 (month)	2.08	1,766	235,467
1964 (maximum shot)	0.25	1,325	1,472,222

Table 20-13. Estimated beryllium release rates from TA-15 explosive testing (duration factors not applied)

	Release Rate for Stated Averaging Period, μg s^{-1}						
Year	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1964	1,472,222	736,111	368,056	46,007	9,201	672	336

Hot Pressing of Beryllium Oxide Powder in Q-Building at TA-1

LANL ordered 6,100 lbs of beryllium oxide (BeO) for use in its reactors by January 15, 1944 (LASL, 1944). For this assessment, it was assumed that the 6,100 lbs of BeO powder that was ordered was actually used in 1944. This amount represents a metric ton of the element beryllium alone.

In order to estimate the amount of BeO (and Be) that would be released, the methods outlined in the *USDOE Handbook of Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* were used (USDOE, 1994). To apply these methods, we estimated an Overall Release Fraction (ORF). The Atmospheric Release Fractions (ARF) and Respirable Factions (RF) were then multiplied to get a range of Overall Release Fractions (ORF). The geometric mean of the ORF, computed as 0.0025 (the square root of the product of the upper and lower bounds), was then applied to the total BeO ordered for 1944.

The ARF was estimated as between 5% of the mass on the high end, and 0.5% of the mass on the low end. The RF was estimated as the mass fraction below five μm diameter. The upper bound was estimated from the known upper size limit (-325 mesh or 44 μm) and a geometric standard deviation of three was assumed for the particle size. Two standard deviations (3×3 = 9) were used to estimate the geometric mean of five μm, which means one half of the mass of BeO was below five μm, and was respirable. A value for respirable fraction (RF) that was ten times smaller was used as an estimate for the lower bound. These values are summarized in Table 20-14.

Table 20-14. Release fraction parameter values for BeO powder processing

	Upper Bound	Lower Bound
Airborne Release Fraction (ARF)	0.05	0.005
Respirable Fraction (RF)	0.5	0.05
Overall Release Fraction (ORF)	0.025	0.00025
Geometric Mean of ORF	0.0025	

Applying the geometric mean of the overall release fraction (0.25%) to the 6,100 pounds of BeO used in 1944 results in a release of 6,932 g of respirable BeO from Q-Building during the year, which would have contained 2,495 g of beryllium. Table 20-15 and Table 20-16 provide the total releases and the release rates with duration factors applied for Q-Building BeO powder pressing during 1944. We can assume that these releases likely continued to occur until the late 1940s, when LANL began to impose more stringent controls on beryllium operations.

Table 20-15. Estimated airborne beryllium releases from BeO powder pressing in Q-Building at TA-1

Year	Duration of Exposure, h	Mass Released, g	Release Rate, μg s^{-1}
1944	1600	2,495	433

Table 20-16. Estimated beryllium release rates from BeO pressing in Q-Building at TA-1 with duration factors applied

	Release Rate for Stated Averaging Period, μg s^{-1}						
Year	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1944	64,475	20,468	12,872	3,600	1,574	152	79

Estimation of Atmospheric Dilution Factors

Beryllium Machining at V-Shop in the Original Technical Area

Based on our review of drawings and 1940s photographs of TA-1, there was no stack on V-Building that met or exceeded the 2.5-times building height criterion for avoiding building wake effects. Accordingly, building wakes will be a consideration. Based on review of drawings and photographs of TA-1, the surface area of V-Building, A_G, was approximately 39 m × 15 m = 585 m^2, the square root of which is 24.2 m; 2.5 times that value is 60.5 m. The distance from V-Building to the nearest residence, the southernmost Sundt apartment on 24th Street, was approximately 165 m (see Fig. 20-1). As this value

exceeds both 2.5-times the square root of A_G and 100 m, this case is represents an exposure outside the near-wake region.

The concentration at the exposure point can therefore be estimated as follows (NCRP, 1996):

$$C = \frac{f\,Q\,B}{u}$$

Where:
- C = average atmospheric concentration at receptor, μg m^{-3}
- f = fraction of time that the wind blows toward the receptor of interest
- Q = effluent release rate (μg s^{-1} in this application)
- B = the Gaussian plume model diffusion factor modified for building wake effects
- u = mean wind speed, m s^{-1}

Because the distance, x, to the nearest potentially exposed individual is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine B. That figure indicates that a value of 9×10^{-4} m^{-2} should be used for B when x = 165 m and A_G falls between 300 and 1,000 m^2. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of two m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows:

$$C/Q = (0.25)\,(9\times10^{-4}\ m^{-2})\,(2\ m\ s^{-1})^{-1} = 1.13\times10^{-4}\ s\ m^{-3}$$

To estimate the airborne beryllium concentration (μg m^3) at the southernmost Sundt apartment on 24th street in Los Alamos, this value can be multiplied by the estimated release rate of beryllium from V-Building (μg s^{-1}). To evaluate episodic releases when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, f will be set to one, and relative concentrations will be four times the C/Q value shown above.

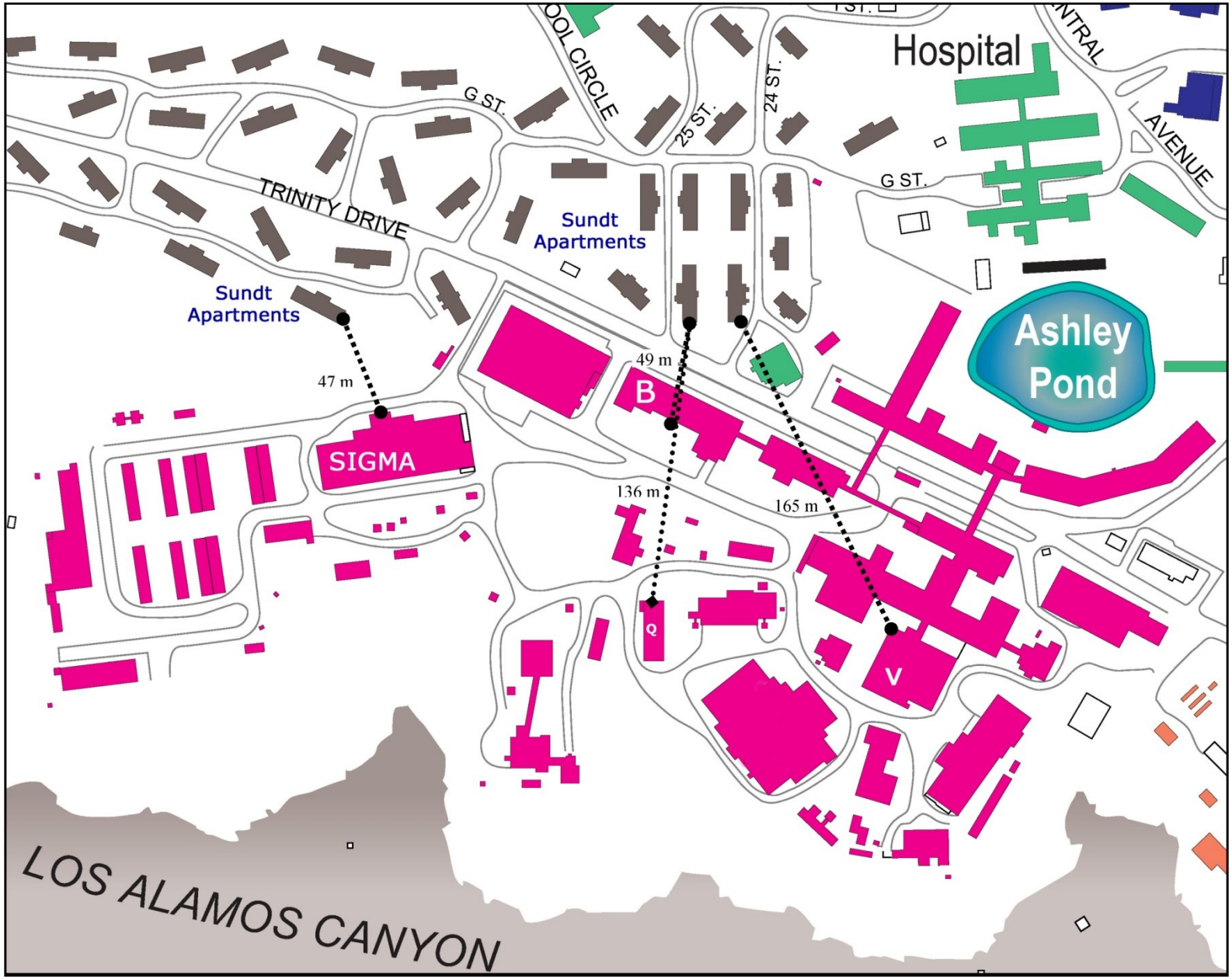

Fig. 20-1. Approximate distances from TA-1 beryllium facilities to nearest residences

Beryllium Oxide Pressing at Q-Building in TA-1

Based on our review of drawings and 1940s photographs of the TA-1, there was no stack on Q-Building that met or exceeded the 2.5-times building height criterion. Because of the stack height, building wakes will be a consideration. Based on our review of drawings and photographs of TA-1, the surface area of the Q-Building, A_G, was approximately 10 m × 5 m = 50 m^2, the square root of which is 7.1 m; 2.5 times that value is 17.7 m. The distance from Q-Building to the nearest residence, the southernmost Sundt apartment on 25th Street, was approximately 136 m (see Fig. 20-1). As this value exceeds both 2.5-times the square root of A_G and 100 m, this case represents an exposure outside the near-wake region.

The concentration at the exposure point can therefore be estimated as follows (NCRP, 1996):

$$C = \frac{f\,Q\,B}{u}$$

Where:
- C = average atmospheric concentration at receptor, μg m^{-3}
- f = fraction of time that the wind blows toward the receptor of interest
- Q = effluent release rate (μg s^{-1} in this application)
- B = the Gaussian plume model diffusion factor modified for building wake effects
- u = mean wind speed, m s^{-1}

Because the distance, x, to the nearest residence is less than two km, Figure 1.5 of NCRP Report 123 was used to determine B. That figure indicates that a value of 2×10^{-3} m^{-2} should be used for B when x = 136 m and A_G falls between 0 and 100 m^2. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of 2 m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows:

$$C/Q = (0.25)\,(2\times10^{-3}\ m^{-2})\,(2\ m\ s^{-1})^{-1} = 2.5\times10^{-4}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from Q-Building (μg s^{-1}) to estimate the airborne beryllium concentration (μg m^3) at the southernmost Sundt apartment on 25th street in Los Alamos. For evaluating episodic releases when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, f will be set to one, and relative concentrations will be four times the C/Q value shown above.

Beryllium Processing in the SM-39 Shops at TA-3

The photographs and documents that have been reviewed indicate that associated releases were not exhausted through a stack that met or exceeded the 2.5-times building height criterion for nearby structures. Because of the stack height, building wake will be a consideration. The distance from Building SM-39 to the closest residential area, Western Area housing, is approximately 960 meters (Fig. 20-2). Based on our review of aerial photographs of SM-39, the width of the north end of the building is approximately 76 m. Based on our review of historical photographs, the height of that building is approximately that of a two story building, or roughly seven m. The cross-sectional area of the north end of the building is therefore 532 m^2, the square root of that value is 23, and 2.5-times the square root is 58. As the distance to the nearest public exposure point exceeds 2.5-times the square root of A_G, this case represents an exposure outside the near-wake region. The concentration at the exposure point can be estimated as follows (NCRP, 1996):

$$C = \frac{f\,Q\,B}{u}$$

Where:
- C = average atmospheric concentration at receptor, μg m^{-3}
- f = fraction of time that the wind blows toward the receptor of interest
- Q = effluent release rate (μg s^{-1} in this application)
- B = the Gaussian plume model diffusion factor modified for building wake effects
- u = mean wind speed, m s^{-1}

Because the distance to the nearest residence, *x,* is less than two km, Figure 1.5 of NCRP Report 123 was used to determine *B*. That figure indicates that a value of 5.5×10^{-5} m^{-2} should be used for *B* when $x = 960$ m and A_G falls between 300 and 1,000 m^2. The NCRP Report 123 method incorporates a value of 0.25 for *f*, and recommends a default of 2 m s^{-1} for *u* when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), *C/Q*, as follows:

$$C/Q = (0.25)\,(5.5\times10^{-5}\ m^{-2})\,(2\ m\ s^{-1})^{-1} = 6.88\times10^{-6}\ s\ m^{-3}$$

To estimate the airborne beryllium concentration (μg m^3) at the southernmost residences of the Western Area in Los Alamos, this value can be multiplied by the estimated release rate of beryllium from the SM-39 shops. For evaluating episodic releases when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, *f* will be set to one, and relative concentrations will be four times the *C/Q* value shown above.

Gun Testing of Weapon Components in the Annex to B-Building in TA-1

Based on our review of drawings and 1940s photographs of the TA-1, there was no stack on B-Building that met or exceeded the 2.5-times building height criterion; therefore, building wakes will be a consideration. The surface area of the building, A_G, is approximately 62 m × 15 m = 930 m^2, the square root of which is 30.5 m; 2.5 times that value is 76.2 m. The distance from the center of the rear (southern facing) side of B-Building to the southernmost Sundt apartment on 25th Street in Los Alamos was 49 m (Fig. 20-1). As this distance is less than both 2.5-times the square root of A_G and 100 m, this case represents exposure in the near-wake region. The concentration at the exposure point can therefore be estimated as follows (NCRP, 1996):

$$C = \frac{f\,Q}{\pi\ \iota\ h\,K}$$

Where: k = a constant of value 1 m, and

h = the smaller of the building height or building width, m.
In this case, building height, h_b (~15 m) is less than its width, h_w (~62 m).

The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows. Because the B-Building gun tests were episodic releases, concentrations will be estimated for the conditions when the wind was blowing toward the identified nearest exposure point by setting f to 1.

$$C/Q = (1)[(3.14) \times (2\ m\ s^{-1}) \times (15\ m)]^{-1} = 1.06 \times 10^{-2}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate (μg s^{-1}) of beryllium from the back center of B-Building to estimate the airborne beryllium concentration (μg m^3) at the southernmost Sundt apartment on 25th Street in Los Alamos.

Fig. 20-2. Approximate distance from Building SM-39 at TA-3 to the southernmost residences of the Western Area in Los Alamos

Beryllium Expended in Explosive Testing at TA-15 (PHERMEX facility)

Based on our review of drawings, photographs, and descriptions of the TA-15 facilities, associated releases were not exhausted through a stack that met or exceeded the 2.5-times building height criterion for nearby structures. Because of the stack height, building wakes (or wakes from nearby structures) will be a consideration.

The distance from the main PHERMEX building to the nearest residential area, the Royal Crest Trailer Park on East Jemez Road, is approximately 4,500 m (see Fig. 20-3). There were no large buildings in the immediate area of PHERMEX. As the distance to the nearest public exposure point exceeded 2.5-times the square root of A_G for all buildings in the area of the testing, this represents an exposure outside the near-wake region. Because the distance to the nearest public exposure point exceeds two km, the concentration at the exposure point can be estimated as follows (NCRP, 1996):

$$C = \frac{f\,Q\,B}{u}$$

Where:
- C = average atmospheric concentration at receptor, μg m^{-3}
- f = fraction of time that the wind blows toward the receptor of interest
- Q = effluent release rate (μg s^{-1} in this application)
- P = the Gaussian plume model diffusion factor as a function of downwind distance assuming a release height (H) at ground level, 0 m.
- u = mean wind speed, m s^{-1}

Because x is greater than 2 km, Figure 1.4 of NCRP Report 123 is used to determine P. That figure indicates that a value of 5×10^{-6} m^{-2} should be used for P when $x = 4500$ m and $H = 0$ m. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of 2 m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows. Because the PHERMEX explosive tests were episodic releases, concentrations will be estimated for the conditions when the wind was blowing toward the identified nearest exposure point by setting f to 1.

$$C/Q = (1)\,(5\times10^{-6}\ m^{-2})\,(2\ m\ s^{-1})^{-1} = 2.5\times10^{-6}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from explosive testing at TA-15 (μg s^{-1}) to estimate the airborne beryllium concentration (μg m^{-3}) at the Royal Crest Trailer Park on East Jemez Road in Los Alamos.

Estimation of Concentrations at Points of Interest

Concentrations of airborne beryllium at the nearest residence ($\mu g\ m^{-3}$) from each identified beryllium operation were estimated by multiplying the estimated release rate ($\mu g\ s^{-1}$) by the applicable relative concentration value ($s\ m^{-3}$). Results are shown in Table 20-17. The estimated release rate and concentration values for BeO powder pressing, V-Shop, and SM-39 Shop releases are presented as six-min, 30-min, and eight-h average values that would be expected to be reached or exceeded once per year, and monthly average concentrations that would be expected to be reached or exceeded 5% of the time. For the explosive tests at TA-15, the results in Table 20-17 for periods longer than a week are values averaged over the periods shown based on 100 shots in a year, each with 0.25-h duration of exposure, that, together, released 10% of the total beryllium reported expended in 1964. For periods shorter than a month, the results are values averaged over the periods shown based on one shot, with 0.25-h duration of exposure occurring during the period and releasing 1.25% of the total beryllium reported as expended in 1964.

Fig. 20-3. Approximate distance from TA-15, PHERMEX area, to the Royal Crest Trailer Park on East Jemez Road in Los Alamos

Table 20-17. Results of screening-level assessment of potential airborne beryllium concentrations in residential areas of Los Alamos

	B-Building Gun Tests[a]	BeO Powder Pressing	V-Shop Machining 1943-48	V-Shop Machining 1949-53	SM-39 Shop 1953 to 1963	SM-39 Shop after 1963	PHERMEX Explosive Tests[a]
Distance to exposure point (m)	49	140	170	170	960	960	4,500
Relative concentration (s m^{-3})	1.1×10^{-2}	2.5×10^{-4}	1.1×10^{-4}	1.1×10^{-4}	6.9×10^{-6}	6.9×10^{-6}	2.5×10^{-6}
Release rates (µg s^{-1}) for stated averaging periods:							
0.1 h:	33,000	64,000	12,000	610	610	3.7	1,500,000
0.5 h:	6,700	20,000	3,900	190	190	1.2	740,000
8 h:	420	3,600	680	34	34	0.20	46,000
730 h (1 month):	140	150	29	1.4	1.4	0.0086	670
Exposure point concentrations (µg m^{-3}) for stated averaging periods:							
0.1 h:	**350**[c,d]	**16**[d]	**1.4**[d]	**0.069**[d]	0.0042	0.000025	**3.7**[d]
0.5 h:	**71**[c,d]	**5.1**[d]	**0.44**[d]	**0.022**[d]	0.0013	0.0000080	**1.8**[d]
8 h:	**4.4**[b,d]	**0.90**[d]	**0.077**[d]	0.0038	0.00023	0.0000014	**0.12**[d]
730 h (1 month):	**1.5**[d,e]	**0.038**[d,e]	0.0033	0.00016	0.000010	0.000000059	0.0017

[a] Episodic releases

[b] Possible exceedance of OSHA/AEC 8-h time weighted average limit = 2 µg m^{-3}

[c] Possible exceedance of OSHA/AEC ceiling limit = 25 µg m^{-3}

[d] Possible exceedance of USEPA Reference Concentration = 0.02 µg m^{-3}

[e] Possible exceedance of National Emission Standard for ambient air averaged over a 30-d period = 0.01 µg m^{-3}

Identification of Relevant Toxicologic or Regulatory Benchmarks

The current OSHA permissible exposure limit (PEL) for occupational exposure to beryllium is two μg m^{-3} (eight-h time weighted average). A ceiling limit of five μg m^{-3} must not be exceeded during the work shift, except that a 30-minute excursion over the ceiling limit is allowed, as long as the air concentration never exceeds 25 μg m^{-3} during the 30-minute period (NIOSH, 2003).

The U.S. Atomic Energy Commission issued "Recommendations for Control of Beryllium Hazards" in August, 1951 that included three standards: a two μg m^{-3} in plant eight-h average beryllium concentration; a 25 μg m^{-3} beryllium air concentration that can never be exceeded; and, a 0.01 μg m^{-3} monthly average concentration at the breathing zone in the neighborhood of a plant handling beryllium (Mitchell and Hyatt, 1957). In 1999, the U.S. Department of Energy established an 8-hr TWA action level for beryllium of 0.2 μg/m^3 that triggers certain workplace precautions and control measures (USDOE, 1999).

The current USEPA Reference Concentration (RfC) for beryllium is 0.02 μg m^{-3} (USEPA, 2009). The RfC is an estimate (with uncertainty spanning an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in studies published in 1996 (Kreiss et al., 1996) and 1949 (Eisenbud et al., 1949).

The Kreiss et al. (1996) occupational exposure study identified a LOAEL (Lowest Observed Adverse Effect Level) for beryllium sensitization in workers exposed to 0.55 μg m^{-3} (median of average concentrations). A cross-sectional study was conducted of 136/139 of the then-current beryllium workers in a plant that made beryllia ceramics from beryllium oxide powder. Measurements from 1981 and later were reviewed, and the study includes area samples, process breathing-zone samples, and personal lapel samples (the last year only). The Eisenbud et al. (1949) study, using relatively insensitive screening methods, suggests a NOAEL (No Observed Adverse Effect Level) of 0.01-0.1 μg m^{-3} in community residents living near a beryllium plant. The LOAEL from the Kreiss et al. study was used for the operational derivation of the RfC because the screening method used in the Eisenbud et al. (1949) study was less sensitive than the method used in the Kreiss et al. (1996) study.

According to the Agency for Toxic Substances and Disease Registry (ATSDR, 2002), evidence suggests that the occurrence of chronic beryllium disease is not related to exposure duration, and can have a long latency period. Very few studies assessing the occurrence of chronic beryllium disease also measured airborne beryllium levels. Eisenbud et al. (1949) found no cases of chronic beryllium disease in residents

living at least 0.75 miles away from a beryllium manufacturing facility. The airborne beryllium concentration at this distance was estimated to range from 0.01 to 0.1 μg m^{-3}.

ATSDR's opinion is that the available database does not support the derivation of acute, intermediate, or chronic duration inhalation MRLs (minimal risk levels). Eisenbud et al. (1949) found no cases of chronic beryllium disease among community residents chronically exposed to 0.01-0.1 μg m^{-3} of beryllium. The study used relatively insensitive methods to detect chronic beryllium disease, however, so it is not know if the residents exposed to 0.01 μg m^{-3} of beryllium would test positive for sensitization or subclinical chronic disease. No human acute or intermediate duration studies that identify a NOAEL or LOAEL for respiratory effects were identified. Animal studies have not identified a reliable NOAEL, and the LOAELs are several orders of magnitude higher than the LOAEL from the Kreiss et al. (1996) occupational exposure study. Although the critical target of beryllium toxicity has been identified as the respiratory tract, an animal model that mimics all aspects of chronic beryllium disease has not been identified. It is therefore inappropriate to derive inhalation MRLs from the animal data (ATSDR, 2002).

Several studies attempt to associate beryllium sensitization and/or chronic beryllium disease with mean, cumulative, and peak exposure levels and employment duration, but no consistent associations have been found. Although the data are insufficient for establishing concentration-response relationships, the available occupation exposure studies do provide exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of 0.5 μg m^{-3}. Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels (0.00003–0.0002 μg m^{-3}) are very low (ATSDR, 2002).

Comparison of Estimated Concentrations with Relevant Benchmarks

The results of the preliminary screening of airborne beryllium concentrations in residential areas of Los Alamos, in terms of estimated airborne concentrations over four different averaging periods, are represented in Fig. 20-4, along with representations of the regulatory limits that can be applied to beryllium concentrations in occupational or public settings. The estimated airborne beryllium concentrations that exceeded one or more of those limits are also identified with footnotes in Table 20-17. While occupational exposure limits are not directly applicable to exposures of members of the public, they are presented as benchmarks to which the calculated concentrations can be compared. Limits imposed on exposures to members of the public are generally lower than those imposed on worker exposures, so concentrations in residential areas must be maintained lower than those accepted in workplace environments.

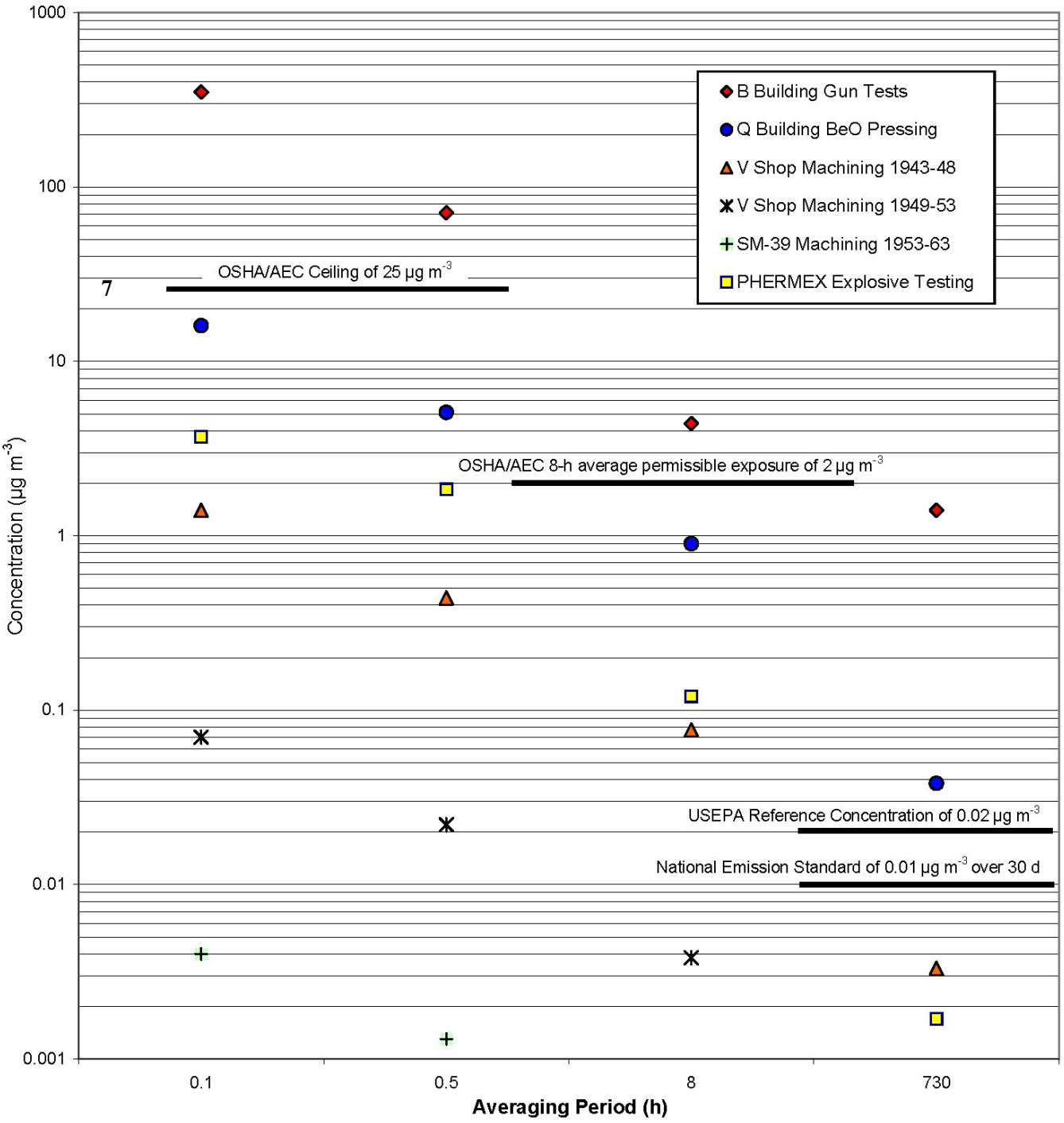

Fig. 20-4. Screening-level estimates of airborne beryllium concentrations in public areas near LANL for six historical operations

Conclusions

The screening results indicate that the eight-h time weighted average permissible exposure limit of two μg m^{-3} for beryllium adopted for workers by OSHA and the AEC could have been exceeded in residential areas by releases from the B-Building gun tests. The OSHA/AEC ceiling limit of 25 μg m^{-3} for workers could also have been exceeded for releases from those tests based on concentrations estimated for 0.5-h and 0.1-h averaging periods. The USEPA reference concentration of 0.02 μg m^{-3} could have been exceeded in residential areas by releases from B-Building gun testing, BeO powder pressing, V-Shop machining, and tests at PHERMEX. The National Emission Standard of 0.01 μg m^{-3} for beryllium in ambient air averaged over a 30-d period could have been exceeded in residential areas from the B-Building gun tests and BeO powder pressing.

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Chapter 21: Public Involvement within the LAHDRA Project

Public involvement played an important role in the LAHDRA project's success, and helped to maintain transparency and openness throughout the project. The CDC and its team of contractor scientists from ChemRisk were dedicated to involving key stakeholders in the project. Project scientists spent many hours interacting with concerned citizens and workers via meetings and roundtable discussions. Public involvement activities and tools used to encourage and facilitate exchange of information included:

- Holding public meetings and roundtable discussions,
- Conducting focus group workshops with pueblo groups and other interested stakeholders,
- Soliciting and reviewing public comments on eight interim project reports,
- Providing public access to project-specific and related websites
- Providing access to an Internet-accessible database of project records,
- Creating a document repository for project records at the University of New Mexico's Zimmerman Library in Albuquerque, and
- Conducting tours of LANL operational areas and other New Mexico historical sites of importance for both LAHDRA project scientists and members of the public.

Public Meetings

Unlike dose reconstruction projects, the LAHDRA project was not advised by a committee formed according to the Federal Advisory Committee Act. In contrast to a dose reconstruction, the LAHDRA project's primary mission was to gather information describing LANL operations associated with off-site releases and to perform initial release prioritization for possible use in future environmental dose reconstruction studies. Advisory committees are often used during detailed dose reconstruction studies in which the availability of site documents and the selection of chemicals and radionuclides for dose reconstruction have been further established based on prior information gathering activities and advanced hazard screening analyses. Because the LAHDRA project activities largely focused on information gathering, the CDC elected to hold public meetings once or twice each year at various locations in the Los Alamos-Española-Taos-Pojoaque-Santa Fe region as a way to update the public as to the project's information gathering progress and its ongoing prioritization of off-site releases.

These meetings provided an open forum for an exchange of information, and were used to inform the public of project activities and to solicit feedback and suggestions. These meetings were publicized through mailings to individuals on the project mailing list, press releases distributed to newspapers, television, and radio stations, and through public notices published in the *Federal Register*. Meetings consisted of:

- A project overview for new attendees,
- Presentations using visual aids such as PowerPoint® slides and historical charts and photos of LANL operations,
- Status updates on specific project aspects (e.g., information gathering activities, focus on key off-site release points),
- Updates on new information gained about historical activities and off-site releases, including descriptions of the quantity and quality of data retrieved from LANL record centers,
- An overview of the challenges encountered while accessing and obtaining relevant documents,
- Status updates on the prioritization of historical releases of chemicals and radionuclides, and
- Sessions for public questions, comments, and suggestions.

In total, 17 meetings and several workshops were held to keep the public informed of project activities and findings. In addition to these meetings, the CDC and project scientists also met with, and offered briefings to, representatives of the Eight Northern Pueblo Council and many of the individual pueblos in Northern New Mexico. Valuable insights were gained from these workshops.

Meeting locations varied among the communities surrounding LANL, and every effort was made to choose familiar locations that offered easy public access. Six meetings were held in Pojoaque, five in Los Alamos, three in Española, two in Santa Fe, and one in Taos.

Figure 21-1. The LAHDRA public meeting held in July, 2008

Updates on noteworthy aspects of the project were also presented at community colleges, as well as at the technical conferences of relevant professional societies (e.g., the Society of Risk Analysis, the Health Physics Society).

Dates and major topics of the public meetings conducted during the project are listed below.

Fig. 21-2. Historical photos of LANL on display at the July, 2008 public meeting

- Thursday, January 25, 2010: Overview of draft final report, topical roundtable discussion groups, presentation of discussion group action items, and a question and answer session.
- Thursday, June 25, 2009: Presentation of the draft final project report, public comment period, and discussion of plans to complete the project.
- Wednesday, July 23, 2008: Project update, status of document review.
- Wednesday, July 18, 2007: Progress of document reviews, discussion of study of plutonium releases in the 1940s and 1950s and public exposures from the Trinity test, report updates.
- Wednesday, July 26, 2006: Project update, status of document review, and presentation of new records database called as DocSleuth.
- Thursday, June 23, 2005: Project update and discussion regarding new project contract.
- Tuesday, July 27, 2004: CDC announces completion of work under first LAHDRA contract.
- Tuesday, March 30, 2004: Release of draft interim report and project team presentations.
- Wednesday, July 9, 2003: Project update and outlook for continued project activities.
- Wednesday, July 10, 2002: Project update and impact of access restrictions on project plans.
- Tuesday, November 27, 2001: Project update and presentation on record access issues.
- Tuesday, April 24 and Thursday, April 26, 2001: Update on project activities, LANL records access at LANL, document reviews and availability.
- Wednesday, September 13, 2000: Project update, interim project report, and discussion of record access issues.
- March 8, 2000: Project update.
- October 5, 1999: Interviews with current and retired workers.
- July 27, 1999: Project update and discussion of sample documents retrieved from LANL record centers.
- February 23, 1999: Project introduction.

Project Reports

A total of eight interim versions of the LAHDRA project report were issued as information gathering progressed and as project scientists gained more knowledge about LANL operations and off-site releases. CDC and project scientists invited public members to review and provide input. Numerous comments and suggestions received during the review process provided valuable information to the project team and were used to address key issues and concerns raised by the public. Public reviews of project reports proved to be another important tool used to ensure openness and transparency throughout the project. Hardcopies and electronic DVD copies of each interim report were made available at public meetings, on the project website, and at the Zimmerman Library in Albuquerque. Comments received on the final draft of the report, as well as project team responses are provided in Appendix 21-A.

Project Website

Early in the project, a website was developed to make project-related information easily available to the public. The website is available at http://www.lahdra.org. Postings and links offered on the LAHDRA website include:

- Announcements of upcoming meetings and workshops,
- Downloadable electronic copies of meeting presentations and presentation slides,
- Notifications of project interim reports and availability of downloadable and hardcopy reports,
- Information about the project team and team member qualifications,
- Downloadable video clips for selected public meetings,
- Downloadable electronic copies of project interim reports, and
- Link to the Internet accessible project records database known as DocSleuth.

Postings on the LAHDRA website also include brief overviews of all public meeting presentations and associated public comments and discussions, summaries of workshops presenting more detailed overviews of project-related topics to interested LANL staff and the general public, information about how to contact LAHDRA team members and access the project document collection and the DocSleuth database at local libraries, and links to related websites.

Database of Project Records: DocSleuth

The project database, called "DocSleuth," was developed in order to facilitate public access to project documents, a key aspect of the project's transparency and openness goal. The database is a compilation of over 8,500 relevant project documents selected and reviewed by project scientists, and is useful for

reconstructing off-site releases from LANL. The Web address for the database is: http://docsleuth.lahdra.org. The database requires an account (an ID and password) for online access, and is a valuable tool for public review of project documents. Each database record consists of an electronic image of the project Document Summary Form (DSF), which highlights the document contents, and offers a text-searchable Adobe® image file format of the document. The online database offers an active search capability, allowing a member of the public to search for a topic area or subject matter by keyword, author, title, document number, or any combination thereof. Members of the public have indicated via comments to the LAHDRA team that they have found the database to be a valuable tool that has allowed them to gain a better understanding of the types of information project scientists have used to gain insight into past releases at LANL. Comments regarding the functionality of the database and availability of LANL records have been very encouraging. Availability of the database to the public has enhanced the public's participation in the project, improved the transfer of information to all interested parties, and has created an additional level of transparency to the project.

For interested members of the public who may have limited access to the Internet, a repository of project records was also established; it is available at the University of New Mexico's Zimmerman Library in Albuquerque.

Public Workshops, Tours, and Interviews

Project scientists invited representatives of local activist groups to workshops and project meetings with LANL staff to address unclassified topics. As an example, a 2007 technical work session with LANL staff included LAHDRA project scientists and representatives from the New Mexico Environment Department and the Executive Director of Concerned Citizens for Nuclear Safety.

The public was also invited to attend unclassified tours of LANL Technical Areas and the Trinity site in southern New Mexico. These tours provided a unique opportunity for the public to learn more about past releases and to exchange information with project scientists. Touring the Trinity Test site and interviewing local residents provided the LAHDRA team with valuable information about the area's characteristics, as well as how people in the area lived and worked, including their use of natural water supplies (ponds/creeks), water and food consumption habits, and other life styles and customs. For example, cisterns (above and below ground water storage tanks) were used for watering livestock, which could be an important exposure pathway to further examine during a dose reconstruction study. Rainwater collected from home rooftops was stored in the cisterns; other uses of the cistern water could be investigated during a dose reconstruction study.

The project also exchanged information with Chimayo resident Peter Malmgren, who, in his "Los Alamos Revisited" oral history program, interviewed 145 of the people who built Los Alamos and/or worked or lived near LANL. These histories, which were placed in the state archives, include the testimony of community members ranging from janitors and housekeepers to senior nuclear weapons specialists.

Project scientists also conducted interviews with members of the public and over 50 current or retired workers in order to fill in gaps regarding historical operations, materials used, and releases that could have occurred as a result of LANL operations. Many interviewees were local residents who voiced their concerns about health risks and past LANL releases, and expressed the need for full transparency of all information being used for the project. The interview process provided another unique opportunity for members of the public to express their concerns and share information potentially relevant to the project. Members of the public were routinely encouraged to contact the CDC or project scientists to learn more about the project, ask questions, or to offer suggestions and comments.

There have been several questions from the community relating to potential future activities stemming from the LAHDRA project. In recent years, a number of major dose reconstructions have been completed by various groups, many of which began with information gathering and historical document retrieval efforts similar to those completed during the LAHDRA project. Appendix 21-B represents examples of such projects and suggests resources from which interested citizens might obtain further information relating to previous dose reconstruction efforts.

News Articles and Press Releases

Periodic newspaper articles and television news reports regarding project-related current events and updates deemed newsworthy were also made available to the public. This form of information sharing was especially useful for those members of the public who were unable access the project websites on the Internet or attend public meetings. Examples of such news articles include:

New Hope for Trinity Downwind Residents - Joline Gutierrez, *Albuquerque Journal*, July 16, 2010, Albuquerque, New Mexico.

Group Briefed on Reduced Chromium Threat - Roger Snodgrass, *Los Alamos Monitor*, January 13, 2010. Los Alamos, New Mexico.

Citizens Get a Crash Course in History - Roger Snodgrass, *Los Alamos Monitor*, January10, 2010. Los Alamos, New Mexico.

Interesting and Disturbing Issues - Letter to the Editor from Ken LaGattuta, *Los Alamos Monitor*, July 13, 2009. Los Alamos, New Mexico.

LANL Winding Down Search for Health Records - Associated Press, *Albuquerque Journal North*, June 30, 2009, Santa Fe, New Mexico.

Gaps Remain As Document Retrieval Project Wind Down - Roger Snodgrass, *Los Alamos Monitor*, June 26, 2009. Los Alamos, New Mexico.

Health Study Meets on Draft Final Report - Roger Snodgrass, *Los Alamos Monitor*, June 10, 2009. Los Alamos, New Mexico.

Guest View: Trinity Effects Re-Evaluated - John Groh, *Albuquerque Journal North,* Thursday, July 31, 2008, Santa Fe, New Mexico.

LANL Airborne Plutonium Reporting Inaccurate - Raam Wong, *Albuquerque Journal North* July 20, 2007 Santa Fe, New Mexico.

Lab Problems Don't Affect CDC Project - Adam Rankin, *Albuquerque Journal North*, July 28, 2004. Santa Fe, New Mexico.

Document Retrieval to Resume - Roger Snodgrass, *Los Alamos Monitor*, July 28, 2004. Los Alamos, New Mexico.

CDC Readies New Contract for Contaminant Study - Roger Snodgrass, *Los Alamos Monitor*, April 4, 2004. Los Alamos, New Mexico.

Feds to Finish Lengthy Study of LANL Pollution - Jeff Tollefson, *The Santa Fe New Mexican*, April 3, 2004: B3. Santa Fe, New Mexico.

Report on LANL Pollution Released - *The Santa Fe New Mexican*, March 26, 2004: B4. Santa Fe, New Mexico.

Lab Disputes CDC Complaints - Jeff Tollefson, *The Santa Fe New Mexican*, July 11, 2003: 1B, 5B. Santa Fe, New Mexico.

CDC Says Lab Withholding Documents - Jeff Tollefson, *The Santa Fe New Mexican*, July 10, 2003. Santa Fe, New Mexico.

Nuke, Toxic Release Probed: Team Studies LANL Data - Adam Rankin, *Albuquerque Journal North*, July 10, 2003, Santa Fe, New Mexico

CDC Reports on Lab Project - Roger Snodgrass, *Los Alamos Monitor*, July 10, 2003. Los Alamos, New Mexico.

Team Seeks Access to Lab Records - *Albuquerque Journal*, Nov 28, 2001. Albuquerque, New Mexico.

Polution Study at Lab Resumes: Security Fears Halted Federal Inquiry for Months - Jennifer McKee, *Albuquerque Journal North*, March 29, 2001: 1A. Santa Fe, New Mexico.

Security Concerns Nearly Halt Lab Study - *Albuquerque Journal*, January 19, 2001. Albuquerque, New Mexico.

Security Threatens Inquiry- Jennifer McKee, *Albuquerque Journal North*, October 31, 2000. Santa Fe, New Mexico.

CDC Access to Laboratory Records Denied- John Marble, *Los Alamos Monitor*, September 14, 2000. Los Alamos, New Mexico.

LANL Contamination Probe at Standstill- Kristen Davenport, *The Santa Fe New Mexican*, September 13, 2000. Santa Fe, New Mexico.

Laboratory Records to be Reviewed by CDC- *LANL News Bulletin*, January 8, 1999. Los Alamos, New Mexico.

Summary

An important commitment of the LAHDRA project was to involve the public early in the process and provide mechanisms and tools that both encouraged and facilitated active public participation in the project. Effective exchange of information between the public and project scientists was made possible through a combination of public meetings, workshops and focus group discussions, site tours, public review of project reports, an internet-accessible project Web site and records database, and interviews with a variety of stakeholders. Sharing of information was enhanced through the availability of the LAHDRA project Web site and DocSleuth, the project records database, as well as mailings and frequent news articles and multi-media reports that provided updates on project activities and significant findings. The project was able to achieve and sustain a high-level of openness and transparency through the effective use of these communication tools. Active public involvement during the LAHDRA project led to a free, open exchange of information and proved to be a highly effective means for addressing public concerns and feedback and provided valuable input that enabled project scientists to produce a more thorough accounting of past LANL operations and environmental releases.

Appendix 21-A: Comments on the Final Draft LAHDRA Report

Over the last eleven years, the LAHDRA team has released eight drafts of this report to the public, with each draft updated based on new information and comments received on the report or at public meetings. In June, 2009, the final draft version of the report was released, and underwent peer-review by a panel of experts at the direction of the CDC. In addition, a public meeting was held in January, 2010 to discuss the final draft report's findings. Comments received from the peer reviewers and the general public have been addressed to the best of our ability in this final report. These comments are broken down by topic (Trinity, plutonium releases, uranium releases, beryllium releases, tritium releases, chemicals, high explosives, other radionuclide-related comments, and overall general comments), and summarized below.

Trinity

Comment: The Trinity site needs to be reexamined; what is the current data? Can an epidemiological study be performed in the surrounding communities?

> *Assessing doses to the public are outside of the current scope of the LAHDRA project; however, such an assessment is something that could be addressed by future work. An epidemiological study is currently being performed by the National Cancer Institute (NCI), and is slated to be released in 2011.*

Comment: The report on the Trinity site by W. R. Hansen as part of Formerly Utilized Sites Remedial Action Program (FUSRAP) should have been mentioned in the draft LAHDRA report.

> *The report by W. R. Hansen was reviewed, and the information presented within was taken into consideration when writing the chapter on Trinity. It can be found within the project database under repository #6005 and #2130.*

Comment: Outside of the plume models of the Trinity test presented in the LAHDRA report, are there any more detailed plume models available?

> *External exposure models related to fallout from the Trinity blast were developed by the Weather Service Nuclear Support Office and Lawrence Livermore National Laboratory (LLNL). Moreover, a source term for the Trinity test was calculated by LLNL scientists and fallout*

patterns were reconstructed on behalf of the USDOE's Off-Site Radiation Exposure and Review Project (ORERP). It is important to note that all assessments of exposure from the Trinity test issued to date are based on monitoring data and have not addressed internal doses received after intake of radioactivity through inhaling or consuming contaminated water or food. Moreover, these assessments have not been subjected to the rigorous quality control processes used in modern dose reconstruction studies that include data validation, application of appropriate data adjustments/correction factors, and uncertainty analysis. For more information on these assessments and information on monitoring results reported by LANL scientists following the blast, see Chapter 10 of the LAHDRA report.

Plutonium releases

Comment: Why is it that only some of the available plutonium soil samples were used to estimate airborne plutonium releases?

Although a list of approximately 650 plutonium soil samples was provided by the LANL environmental staff to use for back calculating plutonium releases, many of these samples were judged to be unsuitable for analysis. Only a few of the 650 samples show clear evidence of a footprint (decrease in plutonium concentration as distance from the source increased). The majority of samples were over 10 km away from known release points. Approximately 100 samples were judged to be impacted by LANL operations based on their plutonium/cesium ratios, and only 37 of these samples had desirable levels of statistical certainty. Most of the samples were a considerable distance from DP Site, and also tended to be located upwind based on average daily weather conditions.

Comment: The second iteration of the back-calculation of plutonium in soil to an estimation of plutonium air releases presented in Chapter 17 of the draft LAHDRA report is biased high because of a large plutonium/cesium ratio.

The LAHDRA team examined the feasibility of estimating airborne plutonium releases using two alternative methods, one of which was a back-calculation based on soil concentrations. The available historical LANL soil measurements that have been used to date in attempting the back-calculation of the LANL plutonium source term are not ideally suited for this task, although the exercise proved useful for understanding the documentation that would important to retrieve,

given the limitations of this method. Please see our revised section on our suggestions for improving the current analysis in Chapter 17.

Comment: Figure 18-1 in the 2009 draft LAHDRA report presents a table of corrected annual releases from DP West Building 12 stacks for 1948 through 1955. The table presented raised a concern because the units of activity were stated to be grams, not a usual measure of activity. Also the table stated "total activity released," not plutonium activity released.

Analyses presented in previous drafts of the LAHDRA report utilized a study by LANL's industrial hygiene group, which was reported by Mr. Edwin Hyatt in 1956. Based on comments received after the 2009 draft LAHDRA report was published, and further review by LAHDRA team members, it was determined that the data presented by Mr. Hyatt were in error. These data, which were presented in Figure 18-1 of the draft report, are not used or presented in the final LAHDRA report.

Comment: The draft LAHDRA report states the need for factor-of-20 correction in the plutonium air effluent data. However, it is suggested that Edwin Hyatt's calculations of plutonium releases from DP West were a factor-of-20 too high, thereby negating the necessity of applying the 20-fold correction factor. Moreover, correction factors for line loss and filter burial were incorrectly selected by the LAHDRA team.

The LAHDRA team agrees with the comment regarding calculations presented by Edwin Hyatt, who was an industrial hygienist at LANL. The Hyatt work was done in error, and the data are not used in the final version of the LAHDRA report. A paragraph has been added in Chapter 17 to explain the reasoning behind this change. Sample line loss and filter burial correction factors have also been updated in the final report, based on analyses performed by LANL staff. Specifically, a sample line loss correction factor equal to five for the years between 1945 and 1958, and two for years between 1959 and 1975, were used based on analysis performed by LANL staff (Fuehne, 2008; repository #7875). Reducing the correction factor beginning in 1959 is based on adding single stage high efficiency particulate air (HEPA) filters to the combined process exhaust system at DP West in 1959. The LAHDRA team also applied a dust loading and filter burial correction factor of 2.33 to plutonium release totals reported by LANL from 1948 through 1959; application of this correction factor was also based on assessments made by LANL staff (Fuehne, 2008; repository #7875). Moreover, a burial factor of 1.6 measured by LANL staff

in the 1970s was applied to data starting in 1959, since the addition of HEPA filtration likely reduced dust loading on the sampling filter.

Comment: Soil concentration data from areas of known liquid effluent releases should not have been used to estimate airborne plutonium releases.

The LAHDRA team agrees that samples impacted by non-air effluents from LANL add uncertainty when back-calculating to air releases. Our suggestions for improving the current analysis in future work can be found in Chapter 17.

Comment: Plutonium autopsy data for the "Clerical Worker" can be found in James McInroy's lab notebook #5, on p. 114; this document is in the LANL archives.

This section of Chapter 17 was removed. In its place, a paragraph discussing the challenges of using autopsy data to establish bounds for LANL releases is discussed. This new section can be found underneath the "Additional Avenues for Investigation" subheading.

Comment: The proximity of residences to LANL plutonium production facilities in the early years makes high doses a real possibility for non-workers – could exposures of some significant fraction of a curie occur in a matter of hours under 'favorable' weather and wind conditions?

While reconstruction of exposure to off-site individuals was outside of the scope of the LAHDRA project, two screening-level assessments for plutonium using the methodology of the National Council on Radiation Protection and Measurements (NCRP) Report No. 123 were performed to evaluate the off-site impact of plutonium releases from DP West. The first assessment was performed for releases during 1949, which is the apparent year of peak emissions for the period prior to 1957. A second screening-level evaluation was performed for releases during 1959, the apparent year of peak emissions after 1957. The year 1957 is significant because it marks the appearance of the Group 18 housing area, resulting in a significant change in the proximity of the nearest residents to DP West. NCRP Report No. 123 provides a series of simple screening techniques that can be utilized to compare estimated dose or risk received from radionuclides released into the environment with a benchmark reference level. For atmospheric releases, the report utilizes three conservative models and parameters. Level I screening employs the simplest and most conservative approach, which assumes a concentration based upon the radionuclide

concentration at a point source emission. Level II screening accounts for dispersion into the atmosphere, while Level III incorporates a more definitive pathway analysis. It is important to emphasize that the results of the screening calculations are strictly for comparison to an environmental standard (limiting value) to determine if compliance with that standard is assured or if further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals. If a dose reconstruction were to occur for members of the public, a more rigorous model accounting for various atmospheric conditions would certainly be used. More information on airborne plutonium releases and the results of the NCRP Report 123 screening-level evaluations can be found in Chapter 18.

Uranium releases

Comment: Can inductively coupled plasma mass spectrometry (ICP-MS) be used to distinguish between natural uranium and detonated uranium?

In short, yes. This type of spectrometry is highly sensitive, and can differentiate between a range of metals (and some non-metals) at very low concentrations. It could feasibly pick up fission products alongside uranium, which could indicate that such uranium had been used in a fission process.

Tritium releases

Comment: Is it possible to get an estimate of tritium releases via evaporation as a waste disposal method?

The LAHDRA project was primarily a data gathering one. However, tritium sampling data were uncovered for the lagoons at TA-53, as well as other sites, and these data could potentially be used as part of future work to estimate tritium releases due to evaporation.

Comment: It does not seem possible that there was no tritium sampling data available prior to 1967.

We did not come across any tritium sampling data that was collected prior to 1967 during our exhaustive document review process.

Comment: Table 7.1 does not include the accidental releases of tritium listed in Chapter 16.

This omission was an oversight by the LAHDRA team, and both the data and the text for Chapter 7 have been appropriately modified.

Other radionuclide-related comments

Comment: Radionuclides were inappropriately grouped during screening level calculations. Specifically, a screening level of 1.00E-07 µCi/mL was used for mixed fission products, even though the U.S. Nuclear Regulatory Commission's Standards for Protection against Radiation (10 CFR 20) states that this value should be used for radionuclides with a half-life under two hours. The draft LAHDRA report groups radionuclides such as Cs-137 and Co-60 into this category, even though their half-lives are significantly longer than two hours.

The LAHDRA team agrees with this comment. Upon review, we found that page three of a document within the LAHDRA project database titled Nuclide Inventory Data (repository # 265) clearly states that the releases for mixed fission products (MFP) should be considered as four month decayed fission products at the time of release, primarily consisting of Cs-137 (which has a maximum permissible concentration (MPC) of 2E-10 uCi/mL) and Sr-90 (with an MPC of 6E-12 uCi/mL assumed to be Y Class). The average of these two would be an MPC of 1E-10 uCi/mL (one half of the Cs-137 value). Using this approach would increase the priority a factor of 1,000 over the current value of 1E-7; this change was incorporated into the final report.

Comment: What proportion of the 15,500 Ci of mixed fission products that were reportedly released from TA-2 (Omega West Reactor) in 1967 is accounted for by radioiodines or precursors? Is it possible that a large portion of this activity was inappropriately attributed to Argon-41?

The LAHDRA team was unable to find any LANL documentation that would permit a comprehensive response to this question. The team understands the importance of the comment, but finding this information is beyond the scope of the LAHDRA project. Several short-lived iodine radionuclides are created during the fission process; however, their release into the environment will depend on many factors, including release mechanisms and any off-gas treatment to release from the stack. Hopefully, the documentation LAHDRA obtained will permit addressing this comment in the future.

Comment: Did the Los Alamos Meson Physics Facility (LAMPF) ever produce kilocurie quantities of radioiodine isotopes?

To answer this question, the LAHDRA team interviewed Mr. Mahlon Wilson, a retired Industrial Fellow at LANL who was involved with the design and construction of the experimental areas at LAMPF. Based on an interview held in March of 2004, Mr. Wilson had no knowledge of LANL producing kilocurie quantities of radioiodine isotopes at LAMPF. The LAHDRA team also contacted staff at Brookhaven National Laboratory (BNL) because BNL was the primary production center for DOE's accelerator-produced isotopes. BNL asserted that LANL was never the DOE's primary production center for accelerator-produced isotopes.

More information specific to episodic releases of radioiodine from LAMPF can be found in repository #4110, which is a series of letters regarding accidental releases of radioiodine during 1985. The letters provide data that indicate abnormally high releases of ^{126}I occurred in July of 1985 at TA-53 due to a CsCl target rupture; however, total releases between July 8th and August 26th, 1985 indicate a total ^{126}I release of only 24.66 mCi.

Comment: Did Los Alamos scientists bombard uranium and thorium targets as large as 2,000 kilograms at the LAMPF in the 1980s? If so, were significant quantities of fission products generated and released?

The LAHDRA team interviewed LANL staff regarding use of uranium and thorium targets as large as 2,000 kilograms at LAMPF. LANL staff insisted that uranium or thorium neutron production targets have never been operated at TA-5; experiments conducted in the 1980s and early 1990s, however, did irradiate uranium and thorium in solid form with the proton beam at low currents for brief periods of time. LANL staff noted that the data from these experiments suggest that mCi quantities of ^{131}I may have been produced and emphasized that such experiments did not create Ci quantities of ^{131}I. LANL's responses to questions posed regarding uranium and thorium targets can be found in repository # 8129. Paralleling LANL's responses, retired Industrial Fellow Mr. Mahlon Wilson indicated that although targets this large were planned, to his knowledge, actual experiments only utilized kilogram amounts of thorium and uranium; his understanding was based on a personal interview he conducted with Gary Russell, a retired LANL scientist. Mr. Wilson's comments can be found in repository #8148.

Comment: Was LANL's Omega West Reactor active in the production of Mo-99, Tc-99, and radioiodines during the 1980s?

Although the Omega West Reactor was operating in the 1980s, it is unclear whether these isotopes were in production. According to a LANL report (LA-UR-00-3854), this reactor was shut down in 1992.

Comment: Was the Solution High Energy Burst Assembly (SHEBA) critical assembly ever operated at a large number of fissions (~10^{18}) without holding tanks to allow decay of the large quantities of radioiodines that would have been produced?

SHEBA I has been estimated to run at approximately 10^{16} fissions per run; it did not have holding tanks for off-gas. It ran from approximately 1980 until 1993. SHEBA II typically operated at around 10^{17} fissions, and had holding tanks for decaying off-gas; it never operated without them. SHEBA II ran from 1993 until approximately 2004. For more information, please refer to the interviews that the LAHDRA team conducted with Charlene Cappiello and Richard Malenfant (repository numbers 8160 and 8161, respectively).

Comment: Can the LAHDRA team provide additional information regarding the medical isotope production facility?

The largest accelerator facility at LANL is housed at TA-53; it is a large accelerator complex originally called the Los Alamos Meson Physics Facility (LAMPF). Today, the complex is called the Los Alamos Neutron Science Center, and it includes LANL's medical radioisotope production facility. Airborne radionuclide releases from this complex consist of a mixture of short-lived radionuclides. These radionuclides are produced when the proton beam from the accelerator is sent through air, or when a fraction of the proton beam is lost through interactions with accelerator components. These "activated" radionuclides, known as mixed activation products (MAP), are composed of particulates from activated dust in air and gaseous activation products from air constituent gases. More information regarding LANL's medical isotope production can be found in Chapter 6.

Comment: Why does LAHDRA utilize ICRP 30 methodology, which relies on the Reference Man model, rather the methodology presented in ICRP publication 71?

Originally published between 1979-1988, ICRP 30, "Limits for Intakes of Radionuclides by Workers," involves calculating dose to workers. Published in 1995, ICRP 71 "Age-Dependent

Doses to Members of the Public from Intake of Radionuclides: Part 4 Inhalation Dose Coefficients," involves age-dependent doses to members of the public from intake of radionuclides. ICRP 30 contains a less complex lung model based on the reference man concept, which is a surrogate to represent "standard" anatomical parameters, and is generally considered to be a more conservative approach than ICRP 71. This model was used simply because a majority of our data came from workers, and the LAHDRA team did not know for certain how old these workers were when the doses occurred. If a dose reconstruction were to occur for members of the public, a more rigorous model incorporating age-adjusted factors would certainly be used to appropriately estimate dose to the public.

Comment: It is not clear how mixed fission product effluents were determined between the years 1961 and 1966.

Estimates for airborne releases of MFP are presented for 1961 through 1994. The data for 1961 through 1972 came from the 1979 LANL Final Environmental Impact Statement (FEIS) documentation (see repository #688). Mixed fission product releases at LANL came from reactor operations (primarily in TA-2, although for a brief period the UHTREX reactor in TA-52 was also included), from hot cell operations with irradiated nuclear materials (in TA-3, TA-21, and TA-48), and from waste disposal operations (at TA-50). MFP is a generic term, however; as of 1973, LANL was applying a definition for reporting purposes under which MFP releases were considered as four month-decayed fission products at the time of release. The "primary biologically significant nuclides" were therefore ^{90}Sr and ^{137}Cs. The data for 1973 forward came from the environmental surveillance reports. For more information on estimates of airborne MFP releases, see Chapter 17 of the LAHDRA report.

Comment: An out-of-date document may have been used to prioritize mixed activation products (MAP).

We believe the commenter was referring to maximum effluent concentration data used for calculating priority indices for MAP, which states that 1.00E-07 µCi/mL should have been used instead of 2.00E-07 µCi/mL. The LAHDRA team agrees that 1.00E-07 µCi/mL should be used in accordance with 10 CFR 20 Appendix B, and tables and text in the report have been altered to reflect this change.

Comment: Plutonium deposition data from worldwide fallout in the Los Alamos area found within Purtymun's 1990 paper should be replaced with more recent data; since the last draft of this report, the Purtymun paper has been discredited.

The LAHDRA team recognizes that more study is needed. While the underlying data may be correct, the conclusions reached by Purtyman may not be accurate. A careful study of fallout will be needed if this work is continued; the text of the report has been updated to reflect this conclusion.

Comment: A generic model should have been used estimate plutonium releases from DP West, rather than National Council on Radiation Protection and Measurements (NCRP) Report 123, *"Screening Models for Releases of Radionuclides to the Atmosphere, Surface Water, and Ground,"* since NCRP 123 was designed to be very conservative.

The LAHDRA team disagrees with this comment. NCRP Report 123 was designed to conservatively estimate releases of radionuclides into the environment, and we used it this way in the report. It is true that NCRP 123 is, by design, very conservative, but screening estimates are expected to be substantial overestimates for most members of the general population, although they should not underestimate the dose to any person. If dose reconstruction work were to be performed, more precise models would certainly be used.

Comment: Data collected by thermoluminescent dosimeters (TLDs) should have been more extensively used in this assessment; dose information is more important than release information.

TLDs are small devices that store energy when impacted with external radiation, and are designed to measure external dose. As discussed in Chapter 14, TLDs were used at LANL as early as 1965 to assess ambient gamma radiation levels and detect potential impacts from radionuclide emissions from the laboratory, particularly larger releases associated with accidents or other uncontrolled events. A directed search for pre-1970 measurement results was unsuccessful during the project, and, by 1970, LANL reduced the number of TLD stations to 60 locations based on prior measurement experience and the recognition that, for future monitoring, one location would provide adequate spatial coverage in some areas that had used two to three TLDs during prior monitoring periods. However, LANL increased the number of TLD locations again in 1981, and has maintained more than 150 locations since that time. Results of these TLD

measurements can provide key historical dose information; however, the LAHDRA project was an information gathering project by design. If a dose reconstruction were to be conducted in the future, TLD data would certainly be utilized.

Comment: Radon and thoron could have affected DP West stack sample results.

As far back as the 1940s, LANL staff were aware of the radon and thoron influence on plutonium air sampling results, and minimized their impact by allowing these daughter products to decay before analyzing the filters. The LAHDRA team retrieved and archived various letters and reports that discuss the stack sampling methods used by LANL, including radon and thoron stack sampling correction methods (repository #197). General information on stack monitoring methods can also be found in Chapter 14 of the report.

Comment: Several questions were asked regarding waste burial of the decommissioned components of the Clementine reactor.

During its exhaustive document search, the LAHDRA project team did not discover the disposal location of the mercury used as coolant in this reactor. Following the reactor's decommissioning, parts were temporarily stored at Area C, and they are believed to be buried there, as well. The project team did not obtain any other information or leads regarding the disposal of Clementine's components.

Comment: Concerns were raised regarding strontium releases to the air and discharges to water, and it was requested that the LAHDRA team perform a more thorough investigation of strontium use, releases, discharges, accidents, and waste disposal practices at LANL.

The LAHDRA team investigated the use and off-site release of ^{89}Sr and ^{90}Sr. Episodic releases of strontium include experiments using high explosives and RaLa at the Bayo Canyon Site (TA-10). The explosions resulted in the dispersion of ^{89}Sr and ^{90}Sr in the form of aerosols and debris to the atmosphere and onto the ground. The LAHDRA team also investigated waterborne releases of ^{89}Sr and ^{90}Sr. Sources of waterborne ^{89}Sr and ^{90}Sr releases from LANL include DP Site (TA-21) and the central liquid waste treatment facility at TA-50. More information on strontium use, releases, and accidents can be found in Chapters 9 and 17 of the LAHDRA report.

Comment: Concerns were raised regarding polonium releases to the air and discharges to water, and it was requested that the LAHDRA team perform a more thorough investigation into polonium use, releases, discharges, accidents, and waste disposal practices at LANL.

The LAHDRA team investigated use and subsequent off-site releases of polonium. One of the main uses of polonium at LANL was in atomic bomb initiators. At TA-1, polonium was handled in D-Building, H-Building, and Gamma Building. The DP East Site facilities were also used to process polonium and actinium and to produce initiators. Additionally, polonium was expended in explosive testing at LANL. The tests used conventional high explosives as well as uranium, beryllium, and polonium radiation sources. These experiments were conducted primarily to verify nuclear weapon initiator designs and were performed in underground chambers and on surface firing pads. More information regarding use and discharge of polonium can be found in Chapter 9 of the LAHDRA report.

Polonium is also addressed in Chapter 17, in the "Data Completeness" Section:

- *"Significant quantities of polonium were used at LANL; however, no effluent data have been found for polonium, other than gross alpha measurements of buildings and stacks at DP East Site, where polonium and other materials were handled and processed. Due to polonium's shorter half-life, perhaps thousands of times more Ci of polonium then plutonium were used at LANL. In LANL's early years, plutonium was considered the most valuable substance on earth, and its use was strictly controlled. Once polonium became more readily available, however, it was not inventoried as closely as plutonium. Large amounts were used in nuclear weapon initiator explosive or destructive tests."*

Beryllium releases

Comment: How does beryllium interact with the environment in air, soil, and water?

*Beryllium dust will settle over land and water. It can enter water from industrial waste; most beryllium compounds will stick to sediments at the bottom of bodies of water. Most beryllium in soil stays bound to soil. More information on how beryllium interacts with the environment can be found on the Agency for Toxic Substances and Disease Registry's website (*http://www.atsdr.cdc.gov/tfacts4.html).

Chemicals Releases

Comment: Why was chromium overlooked by the LAHDRA team?

The LAHDRA team did not overlook chromium; we reported sampling as early as the 1950s in Chapter 14. An accident involving chromium is reported in table 16-1, and we also included it in our analysis of prioritizing chemicals presented in Chapter 19.

High explosives

Comment: Regarding radioactive lanthanum (RaLa) explosive tests, what byproducts are associated with these tests?

LANL used RaLa in the form of ^{140}La was between 1944 and 1962 as an aid in hydrodynamic tests conducted primarily to perfect the implosion process. Oak Ridge National Laboratory initially provided ^{140}La to LANL as a mixture of both ^{140}Ba and ^{140}La. Chemists at LANL's TA-10 chemical process building prepared RaLa sources by separating a solution containing the parent ^{140}Ba and other impurities, such as ^{89}Sr and ^{90}Sr. RaLa was then used in implosion testing at Bayo Canyon (TA-10) from September 21, 1944 through March 6, 1962. Preparing RaLa at TA-10 generated liquid and radioactive wastes that were disposed of in subsurface pits and leaching fields at the site. Almost two million Ci of ^{140}Ba were handled at TA-10 and TA-35 by the time the RaLa program was terminated in 1963. In addition to the release of ^{140}La, about 226 mCi of ^{90}Sr was reportedly released; over 80% of the 226 mCi was released in seven shots in 1945. Further information on RaLa separation and hydrodynamic testing can be found in Chapter 9.

General Comments

Comment: The data set reviewed by the LAHDRA team is incomplete, with reduced access following the events of 9/11 often being cited. Stating in the report that not all historical documents were seen is problematic as far as public perception goes.

The LAHDRA team agrees that the gathered set of information is neither perfect nor complete. Some documents that were generated will never be found because of their loss or destruction, others are difficult to read because of their age and repeated photocopying, and most of the authors and participants from the periods of highest releases have passed away. Moreover, as mentioned in the comment, for the latter part of the project some documents containing certain categories of sensitive information were withheld from review by LAHDRA analysts. Because

documents in these categories include types of information not relevant to studies of off-site releases or health effects, it does not appear that any information needed for assessment of off-site releases was withheld. In spite of the factors mentioned above, the LAHDRA team believes that enough information exists to reconstruct public exposures from the most significant of LANL's releases to a sufficient degree of certainty.

Comment: A very large database, developed during the same period as the LAHDRA team's study of LANL, was available to the LAHDRA team but may not have been adequately utilized. The importance of the Risk Analysis, Communication, Evaluation, and Reduction (RACER) database may be significant.

RACER was developed during the latter part of the LAHDRA project, and was not available when LAHDRA developed draft source terms to aide our understanding of what facilities required the greatest attention for records review. Our review of RACER for older data specific to plutonium in soil has shown that it is the same data provided by LANL to the LAHDRA analysts several years before RACER was funded and developed. RACER does have a great deal of other data in addition to the plutonium in soil data assembled into a convenient database and the LAHDRA team agrees with the comment that RACER should be examined (along with all other data available) in any continuation of this work to ensure that all applicable data is included in any formal environmental dose reconstruction effort.

Comment: Several requests for extended work and dose reconstruction have been made to answer additional questions and to compare to other DOE facilities.

We agree that additional research is needed, but additional work, including a dose reconstruction, is outside of the LAHDRA project's current scope. Future work may be undertaken based on the CDC's recommendation.

Comment: Please take into account the complex terrain of the Pajarito Plateau.

The current analyses represent simplified screening calculations that do not account for details such as these. However, the complex terrain is a factor that would likely be taken into consideration in future refined analyses regarding LANL releases.

Comment: Gaps within the historical data should be addressed.

Every attempt was made to locate and identify all available data. However, data gaps do exist, and we have accounted for these data gaps as best as we could. Future work may fill in these gaps by utilizing alternative data sources, such as soil or autopsy data.

Comment: How is the traditional use of land by Natives integrated into studies and research?

The integration of traditional land use in the areas surrounding LANL is outside the scope of this project. If a dose reconstruction of any sort were to occur, traditional land use would certainly be taken into account when determining what types of doses residents may have received.

Comment: Additional investigation into the "Incidents Documented in H Division Reports," which document chronic problems, episodic events, fugitive and unmonitored emissions, and contamination that had spread onto private property should be performed.

The LAHDRA project team examined a large number of health-related progress reports published by the Health Group, Health Division (H Division), and successor organizations that carried out programs related to worker and environmental health. A complete listing of the documents issued by the H Division and it successor groups that the LAHDRA team located and selected as relevant to off-site releases or health effects is presented as an appendix to Chapter 14 of the LAHDRA report.

Comment: Why wasn't the full length of the Rio Grande included in all maps within the report?

Portions of the Rio Grande were included in maps within the report as a point of reference. The purpose of these maps and figures were to highlight portions of LANL that were of particular interest. In response to this request, Figure 2-4 was revised to include a greater portion of the Rio Grande.

Comment: How are exotic and classified radioactive, toxic, and hazardous materials accounted for in the LAHDRA project?

All significant chemical and radiological releases that were encountered during our document review process are documented within the report.

Comment: It was requested that a summary of anecdotal stories regarding waste burial, dumping, and transportation be included in the report.

The LAHDRA team reviewed waste burial, dumping, and transport activities at LANL, paying considerable attention to the files of Ms. M. A. Rogers, a LANL employee who did extensive work in this area. When Ms. Rogers left the laboratory, she was involved in a lawsuit that resulted in LANL publishing her work. That work represents the most comprehensive effort available to date of compiling waste activities information, including anecdotal stories. Beyond that publication (repository # 3115-3116 in the LAHDRA database), the LAHDRA team also reviewed the legal files associated with Ms. Rogers's case, as well as other documents located in the records center generated by Ms. Rogers during her tenure at LANL. We believe that this collection provides background information useful for any future work in this area. It is our understanding that following Ms. Rogers's departure, LANL used the data she compiled (including anecdotal stories regarding waste burial, dumping, and transportation) in its environmental restoration efforts. Beyond examining the Rogers files, the LAHDRA team made no effort to compile a separate list of burial, dumping, and transportation information, since these activities would not, in most cases, necessarily have resulted in exposures to offsite populations. When such activities did result in offsite releases (such as MDA-g), the LAHDRA team requested the relevant documents for inclusion in the project database.

Comment: Why are activities at the Los Alamos Critical Experiments Facility (TA-18) after 1972 not discussed within the draft LAHDRA report?

These activities are discussed. Table 16-1 discusses an incident at TA-18 in 1979.

Comment: Memos written by Dr. Margo Clark regarding LANL stack emissions are not mentioned in the draft LAHDRA report.

Although the Dr. Clark's memos regarding stack emissions are not specifically mentioned, results of her work can be found within Scott Miller's radioactive airborne effluent release summary covering 1943 to 1991 (repository #2744), which was one of the primary information sources used to estimate airborne releases of radionuclide effluent, as discussed in Chapter 17.

Comment: The LAHDRA team needs to address the reliability of data and how it should be evaluated and weighed.

To some extent, reliability was certainly considered, especially when data were relied upon for screening calculations. However, the purpose of the LAHDRA project was to locate and identify relevant release data and information from historical LANL documents. If future work were to be executed, data would be scrutinized in much more detail to ensure its reliability and accuracy.

Comment: An algebraic error was discovered in 2005 regarding the initial soil assessment of plutonium; old data are reported, and no reference to error or a revised assessment is made in the draft LAHDRA report.

The LAHDRA team acknowledged the error that was due to an inverted constant in interim reports. The error has been corrected in the final report.

Comment: The report claims gradual reduction of soil concentrations of plutonium at one specific location over time; LANL has not reported any significant reduction, and there is no statistically significant decrease.

The LAHDRA team studied ten years of data at one site after a major plutonium release by LANL; this ten year period showed a decline in concentration. However, LANL staff found that inclusion of more data obscured this trend; as such, this discussion has been removed from Chapter 17.

Comment: More should have been reported in the draft report regarding the public's role in the project.

The LAHDRA team agrees with this comment, and Chapter 21 has been expanded to include additional information regarding the public's involvement in the project.

Comment: The LAHDRA team did not evaluate air surveillance monitoring data from a number of stations placed about the lab and community.

AIRNET is a collective array of LANL and regional air monitoring stations; this system is mentioned several times throughout the report.

Comment: The amount of uncertainty associated with geometric standard deviations is misrepresented in Chapter 17, and the executive summary of the draft report regarding plutonium air releases estimated via back-calculation from soil concentrations: 1.2 and 1.3 are not representative of high uncertainty, and 5 and 9 are not representative of low uncertainty.

We agree that the stated uncertainty associated with these geometric standard deviations was incorrect. These discussions have been removed from both Chapter 17 and the executive summary in the final LAHDRA report.

Comment: There were comments requesting minor clarifications, typographical fixes, reference adjustments, and inappropriate language modification.

The LAHDRA report has been thoroughly reviewed for grammatical errors, sentence structure, and consistency between term and acronym use. Changes were made throughout the report.

Appendix 21-B: Previous Dose Reconstruction Projects of AEC/DOE sites

1. Fernald Dosimetry Reconstruction Project

The Fernald Feed Materials Production Center in Ohio was a DOE facility that was part of the United States nuclear weapons production complex from 1951 to 1988. During that period, the facility processed uranium recycled from nuclear production into various uranium products, releasing radioactive material onto the site during the process. In 1990, CDC initiated the Fernald Dosimetry Reconstruction Project in order to examine the degree to which the community may have been affected by that release.

Timeline of Key Events

- 1988-1990
    - CDC was contacted by the United States Congress regarding a potential epidemiologic study in surrounding area
    - CDC determined that a dose reconstruction study was a necessary first step
- 1990-1998
    - CDC's Fernald Dosimetry Reconstruction Project was conducted
    - Draft released to public in August, 1996
    - Final report issued in December, 1998

For more information: http://www.cdc.gov/nceh/radiation/brochure/profile_fernald.htm

2. Hanford Environmental Dose Reconstruction Project (HEDR)

The Hanford nuclear site was built during the 1940s in southeastern Washington and served as a production facility for plutonium used in nuclear weapons. Large amounts of radioactive Iodine-131 and other radioactive material were released into the air between 1944 and 1957, prompting congress to initiate the Hanford Thyroid Disease Study. The Hanford Environmental Dose Reconstruction (HEDR) project was established in support of this study in order to estimate the radiation dose delivered to the thyroid glands of study participants.

Timeline of Key Events

- 1988

    - Congressional mandate for Hanford Thyroid Disease Study
- 1990s
    - CDC-initiated peer review of study conducted by the National Academy of Sciences in 1995, 1997, and 1999
- 2002
    - CDC and the Fred Hutchinson Cancer Research Center released the Final Report in June, 2002

For more information: http://www.cdc.gov/nceh/radiation/brochure/profile_hanford.htm

3. Idaho National Engineering and Environmental Laboratory (INEEL) Dose Reconstruction Project

The INEEL is located in southeastern Idaho, and was used by the federal government as a gunnery test rang during the 1940s. In 1949, the facility was designated as the National Reactor Testing Station by the Atomic Energy Commission, after which it was used to develop and test nuclear reactors and other related facilities. Radioactive waste storage and disposal commenced in 1954, and, in subsequent years, contaminants were released into the environment. In 1992, the CDC was asked to conduct a dose reconstruction in order to determine the level of chemical releases that took place at INEEL, as well as any potential health effects to the surrounding community.

Timeline of Key Events

- 1992
    - CDC asked to perform dose reconstruction
- 2004
    - CDC completed its two-phase analysis, with final results being presented in August, 2004

For more information: http://www.cdc.gov/nceh/radiation/brochure/profile_ineel.htm

4. Savannah River Site Dose Reconstruction Project

The Savannah River Site (SRS), located in South Carolina, was constructed during the early 1950s to produce materials used to fabricate nuclear weapons, especially tritium and plutonium-239. SRS operated from 1954 to 1992, at which point the CDC began a study to determine whether the health of people who lived near the site was affected by past release of chemicals and radioactive materials.

Timeline of Key Events

- 1992
  - CDC initiated an environmental dose reconstruction study at SRS
- 1995
  - Comprehensive data assessment and retrieval phase of project completed in June, 1995
  - In October, 1995, began estimating releases of the most significant radionuclides and chemicals from various facilities
- 2001
  - Final results of estimated releases produced following peer review
- 2006
  - Conclusions and recommendations based on dose reconstruction released in August, 2006

For more information: http://www.cdc.gov/nceh/radiation/brochure/profile_savannah.htm

5. Oak Ridge Dose Reconstruction Project

A large portion of the activities at Oak Ridge National Laboratory has been researching and developing chemical technologies for separating materials from irradiated nuclear fuels and liquid wastes. From late 1994 to early 1999, researchers analyzed past releases of radioactive iodine, mercury, and polychlorinated-biphenyls to the Oak Ridge Reservation and Clinch River in Tennessee that took place as a result of the facility's activities. The project was implemented in order to estimate the previous doses and potential health risks incurred by individuals living near the facility.

Timeline of Key Events

- 1993
  - Results of dose reconstruction feasibility study released
- 1994
  - Oak Ridge Reconstruction Project begins
- 1999
  - Reports issued regarding historical releases of chemicals and dose reconstruction efforts
  - Conclusion of Oak Ridge Dose Reconstruction project

For more information: http://www.cdc.gov/niosh/ocas/pdfs/tbd/k254-r1.pdf

6. Rocky Flats Radiation Dose Reconstruction

The Rocky Flats Plant, located in Colorado, was built in 1951, produced plutonium triggers for nuclear weapons, and processed weapons for plutonium recovery. Following a 1989 agreement between DOE and the state of Colorado, the Colorado Department of Health and Environment began a study to evaluate the doses received and potential health impacts to nearby residents who may have been exposed to chemicals previously released from the plant. The project consisted of an extensive review of previous operations and chemical releases from the plant, as well as a dose reconstruction.

Timeline of Key Events

- 1991
    - Work on Rocky Flats project begins
- 1999
    - Final results of the Rocky Flats study released in September, 1999

For more information: http://www.cdc.gov/niosh/ocas/rocky.html

Chapter 22: Findings of the LAHDRA Project

The LAHDRA project has significantly expanded the quantity of original publicly available documents relating to past LANL operations, LANL personnel activities within New Mexico, and potential public health effects from past environmental releases.

The body of information gathered by LAHDRA document analysts is neither perfect, nor complete, and the project team was only able to scratch the surface in terms of carefully analyzing its contents. Some documents generated at LANL will never be found because of they have been lost or destroyed, others are difficult or impossible to read because of their age and repeated photocopying, and many of the authors and participants from the periods of highest releases have passed away. Yet, in spite of these factors, the members of the LAHDRA study team believe that enough information exists to reconstruct public exposures from the most significant of LANL's releases to a degree of certainty sufficient to allow health professionals to judge if significant elevations of health effects should be expected or measurable.

For the latter part of the project, some documents containing certain categories of sensitive information were withheld from review by LAHDRA analysts. Because documents in these categories included nuclear weapon design details, foreign intelligence, and other types of information that are truly not relevant to studies of off-site releases or health effects, it does not appear that any information needed for dose reconstruction was withheld. This conclusion was reached, thanks, in part, to the existence of an appeal process by which a federal CDC employee could review withheld documents to verify that they contained no needed information. And while text was redacted from many selected documents prior to public release, LAHDRA analysts had access to original and redacted copies, and could verify that the redacted text did not contain information needed for dose reconstruction.

The LAHDRA project has been conducted with a high level of transparency, so that interested parties could review documents selected by team members, perform their own assessments if they so chose, and see if they reach the same conclusions. Significant effort was directed to making DocSleuth and the LAHDRA collection of over 8,000 documents available to all interested parties in the most readily usable fashion. From the beginning of the project, search plans were shared at public meetings, and progress reports highlighted significant milestones, accomplishments, and challenges. Preliminary prioritization assessments were openly shared, even though the possibility existed that information obtained later might prompt revisions of approaches, assumptions, or conclusions. Members of the public, activist groups, and LANL personnel were encouraged to comment on the search plans, draft work products, and make

recommendations for refinement or follow-up work. The quality and utility of the products of the LAHDRA project has been enhanced by this interaction with scientists and members of the public.

The information gathered by the LAHDRA team indicates that airborne releases to the environment from LANL operations were significantly greater than has been officially reported or published to the scientific community to date. The preliminary prioritization steps that have been performed within the LAHDRA project, while quite simple, have yielded information regarding the relative importance of past releases of airborne radionuclides, waterborne radionuclides, and chemicals. In general, the LAHDRA team concluded that early releases were more important (1940s-1960s) than those that followed, and that plutonium was the most important radionuclide in those early years. Airborne activation products from accelerator operations were most important after the late-1970s, and plutonium was the most important constituent for waterborne releases from the mid-1940s on. Among chemicals, organic solvents, as a class, were likely most important, followed by TNT and uranium as a heavy metal.

While prioritization analyses have provided relative rankings of contaminants within categories, the preliminary analyses described herein provided no estimates of concentrations to which members of the public were exposed, resulting intakes, or doses to members of the public that could be converted to estimated health risks or compared to toxicologic benchmarks or decision criteria. Priority Indices for radionuclide releases are based on dilution volumes required to be in compliance with maximum allowable effluent concentrations. They do not reflect how uptake factors vary between radionuclides or the decay that occurs between release point and the location of potential public exposure. And because of the scarcity of details regarding chemical uses and releases before the 1970s, the preliminary ranking process used for toxic chemicals did not incorporate estimates of the fractions of chemical quantities that were on-hand, available for release to the environment, or likely released.

As part of it s effort to prioritize past releases from LANL, the project team was able to advance to screening-level analyses of potential public exposures from airborne releases of plutonium, beryllium, tritium, and uranium. While those analyses yielded information relevant to evaluating the potential health significance of the four materials of interest, it is important to keep in mind that screening results are not meant to represent actual doses received by members of the public, or concentrations to which residents might have been exposed. Such results are, instead, meant to be used to help decide if further investigation of identified releases are warranted.

LAHDRA has been almost exclusively an information gathering effort. To complete historical exposure estimates to members of the public for any of the releases identified and prioritized by the LAHDRA

team, complete pathways of human exposure must be delineated, environmental fate and transport must be characterized, and doses and subsequent health risks to groups who were exposed must be calculated. Methods for performing these steps have been developed and used at numerous other atomic weapons complex sites, but they would need added dimensions in order to properly reflect the effects of LANL's complex surrounding terrain; they would need to take into account, for example, the transport of waterborne releases that often soak into dry stream beds before they travel very far, transported to a large degree by the occasional high flow events that wash contaminants toward the Rio Grande.

LAHDRA analysts have identified a number of historical operations that might be particularly important in terms of off-site exposures. In addition, critical information gaps have been identified in several areas:

- **Early airborne releases of plutonium.** Plutonium was processed in crude facilities in D-Building during World War II, and many roof-top vents were unfiltered and unmonitored. After DP West Site took over plutonium production late in 1945, some releases were filtered, but poor monitoring practices caused releases to be underestimated. Documents indicate that DP West releases for 1948-1955 alone were over 10-times the total reported by LANL for operations before 1973. Screening-level assessments of public exposures from plutonium releases in 1949 and 1959 indicate that airborne plutonium releases warrant further evaluation.

- **Airborne beryllium releases.** LANL used significant quantities of beryllium before its health hazards were fully appreciated, and it was processed very close to residential areas. Preliminary screening indicated that early beryllium processing could have resulted in concentrations in residential areas that exceeded worker exposure limits, the USEPA reference concentration, and the National Emission Standard for beryllium.

- **Public exposures from the Trinity test.** Residents of New Mexico were not warned of the 1945 Trinity blast, informed of any health hazards afterward, or evacuated at any point before, during, or after the test. Exposure rates in public areas near the world's first nuclear explosion were measured at levels 10,000-times higher than currently allowed. Residents reported that fallout "snowed down" for days after the blast. Most residents had dairy cows, and most collected rain water off their roofs for drinking. All assessments of doses from the Trinity test issued to date have been incomplete, in that they have not addressed internal doses received after intakes of radioactivity through inhaling or consuming contaminated water or food.

- **Airborne uranium releases.** LANL has used uranium since its beginnings in enrichments ranging from depleted to highly enriched. It has been machined and fabricated into weapon and

reactor components, and large quantities have been expended in explosive testing. Operational airborne uranium releases warrant further investigation, based on the preliminary screening calculations we performed for TA-3 and TA-21.

- **Tritium releases before 1967.** LANL used tritium as early as 1944, and received it in increasing quantities in the decades that followed for use at ten or more different Lab areas. In spite of this documented use, LANL compilations of effluent data include no tritium releases before 1967. LAHDRA team members located scattered documents describing numerous episodic releases within the 22-year period of tritium usage for which official reports of LANL releases include no data for it. These documents call into question the release estimates reported by LANL for 1967 onward, and indicate that releases before 1967 constitute a data gap that must be addressed if the health significance of LANL tritium releases is to be correctly evaluated.

Based upon the information gathered and the LAHDRA projects findings, the CDC and other interested parties will judge not only if the available information indicates that past releases of any materials could have been so sufficiently high that a detailed investigation of past releases and public exposures is warranted, but also if sufficient information exists to support detailed investigation if the requisite funding could be made available. Potential further investigations that could be undertaken for one or more high priority contaminants could range from screening level assessments of potential public exposures, to more rigorous exposure assessments, similar to those known as dose reconstructions that have been conducted for other MED/AEC/DOE sites. Unlike the prioritization analyses performed to date, these assessments would likely incorporate environmental transport modeling, exposure pathway analysis, and would reflect the uncertainties and variability associated with input data, assumptions, and models, so that the ranges of exposures received by likely members of the public could be specified at a stated level of confidence. Assessments of this type are often performed in an iterative fashion, with uncertainty analyses focusing research on assessment components that contribute most to the overall uncertainty of results. Further refinement can be directed to those elements, and the process can be repeated until the uncertainty of results either becomes acceptable, or cannot be further reduced.