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Los Alamos Historical Document Retrieval and Assessment Project

*Draft Report*

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# A Summary of Historical Operations at Los Alamos National Laboratory and Associated Off-Site Releases of Radionuclides and Other Toxic Materials

**AN IMPORTANT NOTE TO READERS**

Preparation and refinement of this report is a work in progress. There are many more documents to be reviewed, many more interviews to be conducted, and considerably more work to be done in sifting through and interpreting the information that we are locating in order to develop an accurate picture of past operations, releases, and potential health effects. Many of the documents that we have identified as relevant to off-site releases, and have described in our project information database, have not yet been publicly released and are not yet available for our use in preparing this report and advancing our prioritization of past releases. Even though this report is very preliminary in nature, we are sharing it publicly so that interested parties can see the type of information we are finding, be introduced to the approaches we are taking to interpret the information that we find, and offer comments and criticism as to how the report could be improved as we progress.

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Submitted to the Centers for Disease Control and Prevention by

ENSR INTERNATIONAL

Prepared by ENSR International and Shonka Research Associates, Inc.

**DRAFT DOCUMENT**

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# 1. INTRODUCTION TO THE 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The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project began in early 1999.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, National Center for Environmental Health. Much of the work of the project is being conducted by contractors to CDC, namely ENSR International and subcontractors Shonka Research Associates and Tech Reps, Inc.

## 1.1 The Purpose of the Project

The primary purpose of the Los Alamos Historical Document Retrieval and Assessment project (LAHDRA) is to identify the information that is available concerning past releases of radionuclides and chemicals from Los Alamos National Laboratory (LANL). Sited in northern New Mexico and owned by the Department of Energy, LANL has been managed by the University of California since 1943, when the Laboratory was born as part of the Manhattan Project to create the first atomic weapons. LANL's responsibilities have expanded since then, 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 including criticality experiments and 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, the Centers for Disease Control and Prevention (CDC) will work with stakeholders to determine if more-detailed assessments of past releases are warranted. Should additional investigations be warranted, they might be in the form of screening-level evaluations, or could progress to detailed dose reconstruction for those releases of highest priority.

In more specific terms, CDC's model of dose reconstruction involves a process that is broken up 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 is currently in various stages of this process at INEL, Savannah River, and Los Alamos. Various stages of the process may overlap in time, 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 process of information gathering and assessment is partially complete, and will continue until all available records at Los Alamos have been reviewed.

## 1.2 Methods of Information Gathering by the Project Team

A team of document analysts has been reviewing documents at Los Alamos since early 1999. When information that is relevant to off-site releases or health effects from Los Alamos operations is found, a Document Summary Form (DSF) is completed (Figure 1). Each document is assigned a Repository Number, and the information from the DSF is entered into the project information database. Many of the citations of documents used as references for this report have their Repository Numbers included. Documents that are reviewed are categorized as to their level of relevance to off-site releases or health effects, and copies are made of the most relevant documents. Document analysts categorize records into the following classes:

- Category 1 documents are documents that a competent scientist would use in *estimating* off-site releases or health effects from any operations at LANL or other LANL-sponsored operations within New Mexico. Category 1 documents will be copied, and summaries of them will be entered into the project information database.

- Category 2 documents are documents that contain supporting information that could be useful in *confirming* estimated release quantities or health effects from any operations at LANL or other LANL-sponsored operations within New Mexico. Category 2 documents will not normally be copied, but summaries of them will be entered into the project information database.

- Category 3 documents are documents that could be used to estimate releases or health effects from any nuclear weapons complex site outside of New Mexico, or from operations sponsored by groups other than LANL at New Mexico sites other than LANL. Category 3 documents will not normally be copied, but summaries of them will be entered into the project information database.

- Category 4 documents are documents that are not relevant to estimation or confirmation of releases or health effects from any sites of interest. These records will not normally be photocopied, nor will summaries of them be entered into the project database.

Documents that are photocopied must go through several review processes before public release is possible. A classification review must occur, personal information that is protected under the Privacy Act must be identified and removed, and a legal review must be done to identify any information that is attorney-client privileged.

The products of this project will be:

- A document that summarizes historical Los Alamos operations, identifies materials that were likely released, and, to the extent possible, characterizes the relative priorities that the various releases warrant in terms of investigating potential off-site releases and health effects. This document will evolve into that report.

- A database that describes the relevant documents that were located by the project team.

- Sets of copies of the most relevant documents, to be made available in a reading room in Albuquerque (and hopefully, in the future, also in Los Alamos and/or Española).

**Figure 1: LAHDRA Document Summary Form**

| | | | |
|---|---|---|---|
| DOCUMENT TITLE: | | | |
| DOCUMENT NUMBER: | | PROJECT: | |
| AUTHOR (S): | | | |
| PUBLICATION DATE: | | DATA TIME PERIOD: start: _____ stop: _____ | |
| ORGANIZATION: | TECHNICAL AREA: | | |
| CDC DOCUMENT CATEGORY: 1 2 3 | DOCUMENT TYPE: 1. Box 2. Document 3. Computer file 4. File cabinet 5. Interview 6. Microfilm 7. Notebook | | |
| ORIGINAL LOCATION OF DOCUMENT: | | | |
| POINTS OF CONTACT FOR DOCUMENT: 1. | | 2. | |
| 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 _____ | | | |
| ANALYST'S COMMENTS ON DOCUMENT'S RELEVANCE TO DOSE RECONSTRUCTION | | | |
| ANALYST: | | DATE REVIEWED: | |
| Repository Use Only | | | |
| Repository#: | Date Entered into Database: | Signature: | |

## 1.3 About This Report

This draft report represents an early assembly of summary information by the project team regarding historical operations at Los Alamos, the materials that were used, the materials that were likely released off site, and the relative priority of identified releases. The information in this draft report was obtained from records reviewed at Los Alamos by the project team, some books and reports that are publicly available, and some interviews with past and current Los Alamos workers.

Preparation and refinement of this report is a work in progress. There are many more documents to be reviewed, many more interviews to be conducted, and considerably more work to be done in sifting through and interpreting the information that we are locating in order to develop an accurate picture of past operations, releases, and potential health effects. We began reviewing records in Los Alamos in early 1999, and after more than a year of document review, we were finally to the point that procedures for review and public release of documents were being agreed upon and implemented. Then came the Cerro Grande fire that shut down the Laboratory, followed by the period of heightened security that has resulted in all members of the project team being excluded from access to all classified repositories at Los Alamos. Our access to the classified repositories has been restored, under a number of Special Security Plans that outline specific procedures under which access will be granted, documents will be reviewed, and release of information can occur.

As the project continues, we will bring about public release of many more historical documents. We will continue to refine this report, and we plan to periodically issue new drafts as the project continues. Each version will be more complete in its depiction of historical operations and releases, and our assessment of the relative priorities of the past operations and releases will more clearly and defensibly identify those that warrant highest priority and those that appear to have been less important in terms of potential off-site health hazards. Even though this report is very preliminary in nature, we are sharing it publicly so that interested parties can see the type of information we are finding, be introduced to the approaches we are taking to interpret the information that we find, and offer comments and criticism as to how the report could be improved as we progress. We invite you to provide your comments and follow us in this process.

# 2. HISTORY OF LOS ALAMOS OPERATIONS

## 2.1 The Missions of Los Alamos Laboratory

When the Los Alamos facility was initiated, it had a single mission— perfection of 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 concept in Figure 2 (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, Los Alamos personnel initially experimented with use of enriched uranium ($^{235}U$) and plutonium as the fissionable material. Other materials that were needed included the 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).

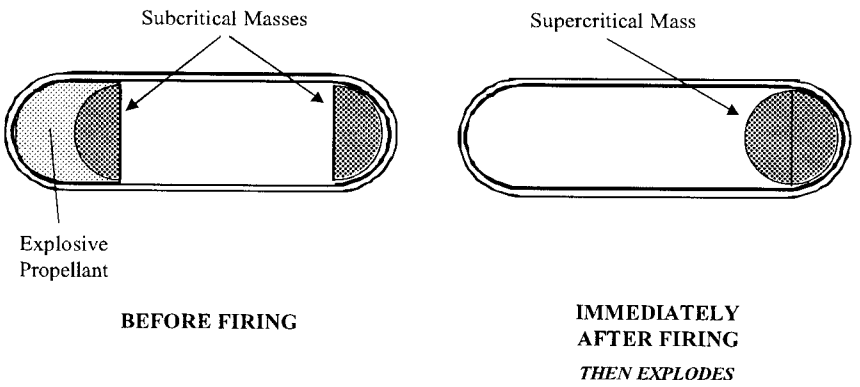


**Figure 2: Concepts of a Gun-Assembled Atomic Weapon**

Early development work centered on use of $^{235}U$ or $^{239}Pu$ in gun-assembled devices. Top priority was given to development of a plutonium-projectile gun device, with posed more problems than the uranium design due to tighter purity specifications and the need for a faster assembly velocity. In July 1944, it was found that the plutonium that was being received at Los Alamos would not work in gun-assembled weapons due to 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 it was 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 detonation of a high-explosive implosion system. The implosion type bomb is depicted conceptually in Figure 3 (LANL, 1983).

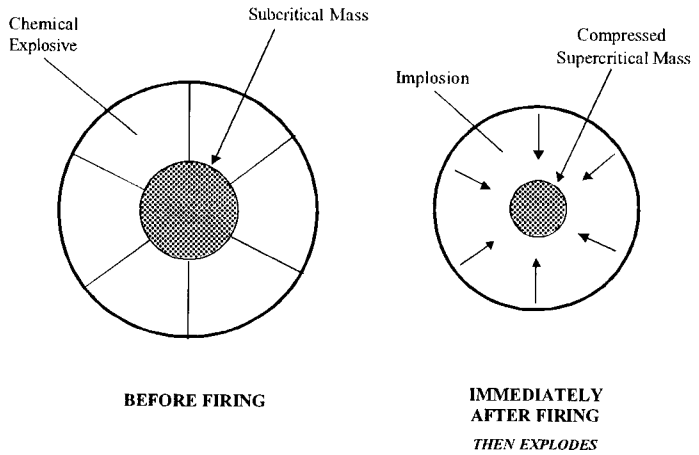


**Figure 3: Concepts of the Implosion-Assembled Atomic Weapon**

To develop and build implosion-assembled devices, much experimentation had to be done with getting chemical high explosives to precisely assemble something with great symmetry, in contrast to their typical uses in blowing things up. Work on high explosives centered on achieving microsecond timing of detonations at the surface of the explosive and use of "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 development of "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 Los Alamos' 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 Figure 4 (LANL, 1983).

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

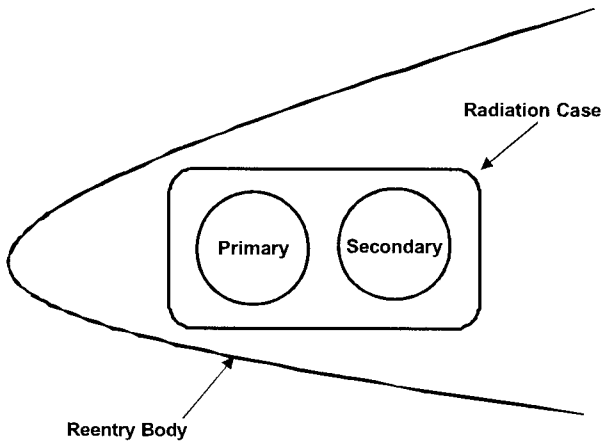


**Figure 4: Concepts of a Staged Nuclear Weapon**

After World War II, Los Alamos scientists and engineers were involved in development and testing of numerous designs of nuclear devices that were more and more powerful, compact, reliable, dependably deployable in the field, and contained in a variety of delivery vehicles suited to various combat objectives. They were involved in many tests of nuclear devices within the continental United States, in the Pacific, and in Alaska, including some that were part of the Plowshare program that 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, Los Alamos was 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, Los Alamos was called upon to perform special functions in its backup role. For example, because of an accident at the Hanford Plutonium Finishing Plant in 1984, plutonium was sent in oxide form to Los Alamos for conversion to metal (USDOE, 1997). Special activity at Los Alamos 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 development and production of the 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 nonmilitary development and fundamental research. For example, Los Alamos developed one of the largest experimental machine shops in the country. The 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 Los Alamos. 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 Los Alamos, and the plasma

thermocouple program explored methods for drect conversion of fission energy to electricity for propulsion of potential spacecraft application.

Operations at Los Alamos have taken place in land divisions called Technical Areas, or TAs. Table 1 contains a listing of these Technical Areas, including some that have been abandoned, some that were combined with other TAs, and some that were cancelled before they ever became operational. Figure 5 shows the locations of the modern-day Technical Areas, and Figure 6 presents a timeline of some selected operations and activities at (or related to) Los Alamos.

References:

LANL, 1983. "Nuclear Weapon Illustrations", Classification Bulletin No. 9. August.

Serber et al., 1992. "The Los Alamos Primer– The First Lectures on How to Build An Atomic Bomb." Contains an annotated version of report LA-1, "The Los Alamos Primer" (1943). University of California Press, Berkeley.

USDOE, 1997. "Linking Legacies– Connecting the Cold War Nuclear Weapons Production Processes To Their Environmental Consequences." DOE/EM-0319. U.S. Department of Energy, Washington, DC. January.

**Table 1: Los Alamos Technical Areas of the Past and Present**

| | |
|---|---|
| TA-0 | Los Alamos Townsite |
| TA-1 | Original Main Technical Area (not currently active): |
| TA-2 | Omega TA-3, Core Area: [a.k.a. "South Mesa Site"] |
| TA-4 | Alpha Site: Removed in 1956 |
| TA-5 | Beta Site: Former Firing Site |
| TA-6 | Two-Mile Mesa Site |
| TA-7 | Gomez Ranch Site. Abandoned in 1945. Former Firing Site. |
| TA-8 | GT Site (or Anchor Site West) |
| TA-9 | Anchor Site East |
| TA-10 | Bayo Canyon Site (not currently active; "removed in 1963" ) |
| TA-11 | K Site |
| TA-12 | L Site: |
| TA-13 | P Site: Incorporated with S Site (TA-16) |
| TA-14 | Q Site |
| TA-15 | R Site |
| TA-16 | S Site |
| TA-17 | X Site: Canceled |
| TA-18 | Pajarito Laboratory |
| TA-19 | East Gate Laboratory: Released to AEC in 1962 |
| TA-20 | Sandia Canyon Site: Abandoned in 1957. Former Firing Site. |
| TA-21 | DP Site |
| TA-22 | TD Site |
| TA-23 | NU Site: Removed in 1950 |
| TA-24 | T Site: Incorporated with S Site (TA-16) |
| TA-25 | V Site: Incorporated with S Site (TA-16) |
| TA-26 | D Site: Removed in 1966 |
| TA-27 | Gamma Site: Abandoned in 1945 |
| TA-28 | Magazine Area A |

**Table 1: Los Alamos Technical Areas of the Past and Present (continued)**

TA-29 Magazine Area B: Abandoned in 1957
TA-30 Electronics Test Area: Removed in 1945
TA-31 East Receiving Yard: Removed in 1954
TA-32 Medical Research Laboratory: Removed in 1954
TA-33 HP Site
TA-34 New Laboratory Warehouse Area: Canceled
TA-35 Ten Site
TA-36 Kappa Site:
TA-37 Magazine Area C
TA-38 Monte Rey Site: Canceled
TA-39 Ancho Canyon Site
TA-40 DF Site
TA-41 W Site
TA-42 Incinerator Site: Abandoned in 1970.
TA-43 Health Research Laboratory
TA-44 Los Angeles Shop: Abandoned in 1958
TA-45 Radioactive Liquid Waste Treatment Plant (not currently active):
TA-46 WA Site
TA-47 BR Site (Brunns Railhead in downtown Santa Fe). Abandoned in 1958.
TA-48 Radiochemistry Site
TA-49 Frijoles Mesa Site
TA-50 Waste Management Site
TA-51 Environmental Research Site
TA-52 Reactor Development Site
TA-53 Los Alamos Neutron Science Center
TA-54 Waste Disposal Site
TA-55 Plutonium Facility Site
TA-56 Subterrne Basalt Site. Abandoned 1976
TA-57 Fenton Hill Site
TA-58 Reserved for experimental sciences tied to programs currently located at TA-3.
TA-59 Occupational Health Site
TA-60 Sigma Mesa
TA-61 East Jemez Road
TA-62 Reserved for experiments, public/corporate interface, environmental research, buffer zones.
TA-63 A major growth area at the Laboratory, environmental and waste management functions.
TA-64 Central Guard Facility and headquarters for the Hazardous Materials Response Team.
TA-65 Technical Area not currently active or never assigned?
TA-66 This site is used for industrial partnership activities.
TA-67 This is a dynamic testing area that contains significant archeological sites.
TA-68 This is a dynamic testing area that contains archeological and environmental study areas.
TA-69 Undeveloped; serves as an environmental buffer for the dynamic testing area.
TA-70 Undeveloped; serves as an environmental buffer for the high-explosives test area.
TA-71 Undeveloped; serves as an environmental buffer for the high-explosives test area.
TA-72 This is the site of the Protective Forces Training Facility.
TA-73 This area is the Los Alamos Airport.
TA-74 Otowi Tract: contains archeological sites, an endangered species breeding area, water wells.

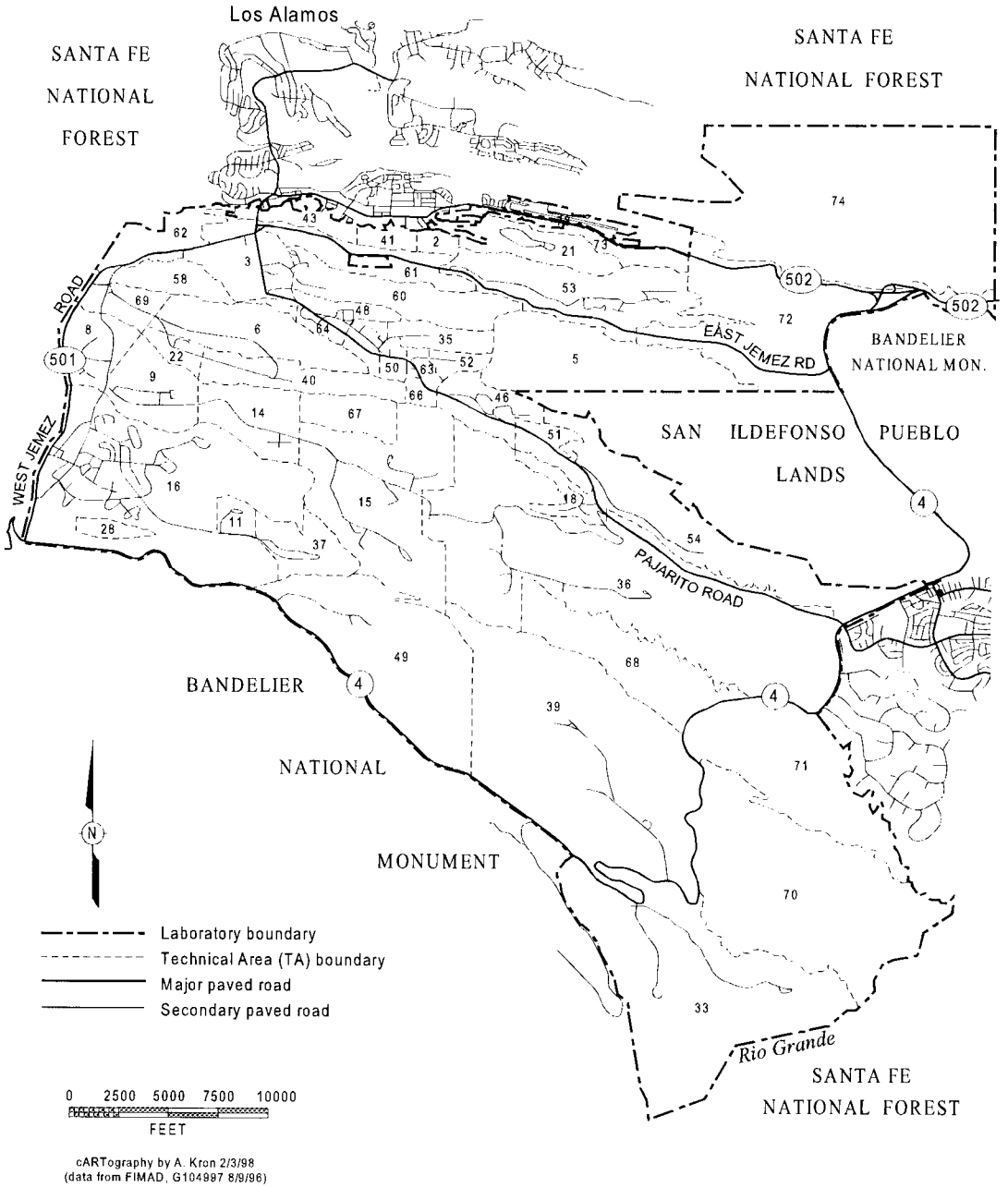


**Figure 5: Map of LANL technical areas and roads.**

Los Alamos Historical Document Retrieval and Assessment Project

*Draft Report*

# A Summary of Historical Operations at Los Alamos National Laboratory and Associated Off-Site Releases of Radionuclides and Other Toxic Materials

## AN IMPORTANT NOTE TO READERS

Preparation and refinement of this report is a work in progress. There are many more documents to be reviewed, many more interviews to be conducted, and considerably more work to be done in sifting through and interpreting the information that we are locating in order to develop an accurate picture of past operations, releases, and potential health effects. Many of the documents that we have identified as relevant to off-site releases, and have described in our project information database, have not yet been publicly released and are not yet available for our use in preparing this report and advancing our prioritization of past releases. Even though this report is very preliminary in nature, we are sharing it publicly so that interested parties can see the type of information we are finding, be introduced to the approaches we are taking to interpret the information that we find, and offer comments and criticism as to how the report could be improved as we progress.

Version 2G
February 22, 2002

Submitted to the Centers for Disease Control and Prevention by

ENSR INTERNATIONAL

Prepared by ENSR International and Shonka Research Associates, Inc.

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# 1. INTRODUCTION TO THE 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, National Center for Environmental Health. Much of the work of the project is being conducted by contractors to CDC, namely ENSR International and subcontractors Shonka Research Associates and Tech Reps, Inc.

## 1.1 The Purpose of the Project

The primary purpose of the Los Alamos Historical Document Retrieval and Assessment project (LAHDRA) is to identify the information that is available concerning past releases of radionuclides and chemicals from Los Alamos National Laboratory (LANL). Sited in northern New Mexico and owned by the Department of Energy, LANL has been managed by the University of California since 1943, when the Laboratory was born as part of the Manhattan Project to create the first atomic weapons. LANL's responsibilities have expanded since then, 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 including criticality experiments and 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, the Centers for Disease Control and Prevention (CDC) will work with stakeholders to determine if more-detailed assessments of past releases are warranted. Should additional investigations be warranted, they might be in the form of screening-level evaluations, or could progress to detailed dose reconstruction for those releases of highest priority.

In more specific terms, CDC's model of dose reconstruction involves a process that is broken up 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 is currently in various stages of this process at INEL, Savannah River, and Los Alamos. Various stages of the process may overlap in time, 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 process of information gathering and assessment is partially complete, and will continue until all available records at Los Alamos have been reviewed.

## 1.2 Methods of Information Gathering by the Project Team

A team of document analysts has been reviewing documents at Los Alamos since early 1999. When information that is relevant to off-site releases or health effects from Los Alamos operations is found, a Document Summary Form (DSF) is completed (Figure 1). Each document is assigned a Repository Number, and the information from the DSF is entered into the project information database. Many of the citations of documents used as references for this report have their Repository Numbers included. Documents that are reviewed are categorized as to their level of relevance to off-site releases or health effects, and copies are made of the most relevant documents. Document analysts categorize records into the following classes:

- Category 1 documents are documents that a competent scientist would use in *estimating* off-site releases or health effects from any operations at LANL or other LANL-sponsored operations within New Mexico. Category 1 documents will be copied, and summaries of them will be entered into the project information database.

- Category 2 documents are documents that contain supporting information that could be useful in *confirming* estimated release quantities or health effects from any operations at LANL or other LANL-sponsored operations within New Mexico. Category 2 documents will not normally be copied, but summaries of them will be entered into the project information database.

- Category 3 documents are documents that could be used to estimate releases or health effects from any nuclear weapons complex site outside of New Mexico, or from operations sponsored by groups other than LANL at New Mexico sites other than LANL. Category 3 documents will not normally be copied, but summaries of them will be entered into the project information database.

- Category 4 documents are documents that are not relevant to estimation or confirmation of releases or health effects from any sites of interest. These records will not normally be photocopied, nor will summaries of them be entered into the project database.

Documents that are photocopied must go through several review processes before public release is possible. A classification review must occur, personal information that is protected under the Privacy Act must be identified and removed, and a legal review must be done to identify any information that is attorney-client privileged.

The products of this project will be:

- A document that summarizes historical Los Alamos operations, identifies materials that were likely released, and, to the extent possible, characterizes the relative priorities that the various releases warrant in terms of investigating potential off-site releases and health effects. This document will evolve into that report.

- A database that describes the relevant documents that were located by the project team.

- Sets of copies of the most relevant documents, to be made available in a reading room in Albuquerque (and hopefully, in the future, also in Los Alamos and/or Española).

**Figure 1: LAHDRA Document Summary Form**

| | | | |
|---|---|---|---|
| DOCUMENT TITLE: | | | |
| DOCUMENT NUMBER: | | PROJECT: | |
| AUTHOR (S): | | | |
| PUBLICATION DATE: | DATA TIME PERIOD: start: _____ stop: _____ | | |
| ORGANIZATION: | TECHNICAL AREA: | | |
| CDC DOCUMENT CATEGORY: 1 2 3 | DOCUMENT TYPE: 1. Box 2. Document 3. Computer file 4. File cabinet 5. Interview 6. Microfilm 7. Notebook | | |
| ORIGINAL LOCATION OF DOCUMENT: | | | |
| POINTS OF CONTACT FOR DOCUMENT:<br>1. | 2. | | |
| KEYWORDS: (circle or write in)<br>Atmosphere<br>Design<br>Ground Water<br>Surface Water | Biological<br>Effluent<br>Operational<br>Terrestrial | Chemical<br>Environmental<br>Radiation<br>Uncertainty | Chronic Release<br>Episodic Release<br>Radionuclide<br>Waste Disposal |
| Other: _____ | | | |
| Document Abstract: Original _____ | | | |
| ANALYST'S COMMENTS ON DOCUMENT'S RELEVANCE TO DOSE RECONSTRUCTION | | | |
| ANALYST: | | DATE REVIEWED: | |
| Internal Use Only | | | |
| Repository#: | Date Entered into Database: | Signature: | |

## 1.3 About This Report

This draft report represents an early assembly of summary information by the project team regarding historical operations at Los Alamos, the materials that were used, the materials that were likely released off site, and the relative priority of identified releases. The information in this draft report was obtained from records reviewed at Los Alamos by the project team, some books and reports that are publicly available, and some interviews with past and current Los Alamos workers.

Preparation and refinement of this report is a work in progress. There are many more documents to be reviewed, many more interviews to be conducted, and considerably more work to be done in sifting through and interpreting the information that we are locating in order to develop an accurate picture of past operations, releases, and potential health effects. We began reviewing records in Los Alamos in early 1999, and after more than a year of document review, we were finally to the point that procedures for review and public release of documents were being agreed upon and implemented. Then came the Cerro Grande fire that shut down the Laboratory, followed by the period of heightened security that has resulted in all members of the project team being excluded from access to all classified repositories at Los Alamos. Our access to the classified repositories has been restored, under a number of Special Security Plans that outline specific procedures under which access will be granted, documents will be reviewed, and release of information can occur.

As the project continues, we will bring about public release of many more historical documents. We will continue to refine this report, and we plan to periodically issue new drafts as the project continues. Each version will be more complete in its depiction of historical operations and releases, and our assessment of the relative priorities of the past operations and releases will more clearly and defensibly identify those that warrant highest priority and those that appear to have been less important in terms of potential off-site health hazards. Even though this report is very preliminary in nature, we are sharing it publicly so that interested parties can see the type of information we are finding, be introduced to the approaches we are taking to interpret the information that we find, and offer comments and criticism as to how the report could be improved as we progress. We invite you to provide your comments and follow us in this process.

# 2. HISTORY OF LOS ALAMOS OPERATIONS

## 2.1 The Missions of Los Alamos Laboratory

When the Los Alamos facility was initiated, it had a single mission— perfection of 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 concept in Figure 2 (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, Los Alamos personnel initially experimented with use of enriched uranium ($^{235}U$) and plutonium as the fissionable material. Other materials that were needed included the 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).

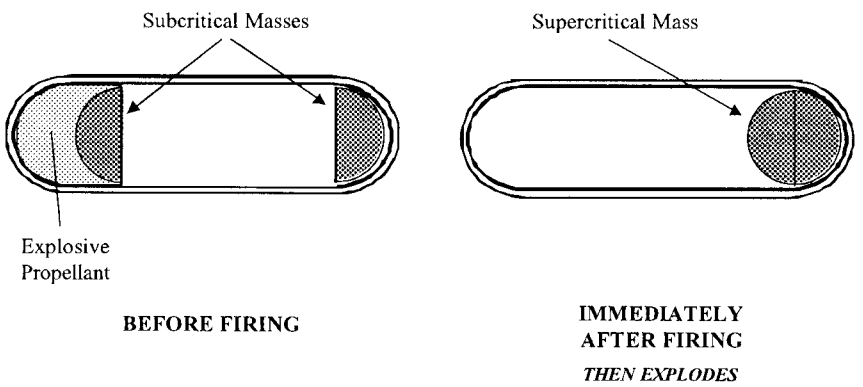



**Figure 2: Concepts of a Gun-Assembled Atomic Weapon**

Early development work centered on use of $^{235}U$ or $^{239}Pu$ in gun-assembled devices. Top priority was given to development of a plutonium-projectile gun device, with posed more problems than the uranium design due to tighter purity specifications and the need for a faster assembly velocity. In July 1944, it was found that the plutonium that was being received at Los Alamos would not work in gun-assembled weapons due to 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 it was 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 detonation of a high-explosive implosion system. The implosion type bomb is depicted conceptually in Figure 3 (LANL, 1983).

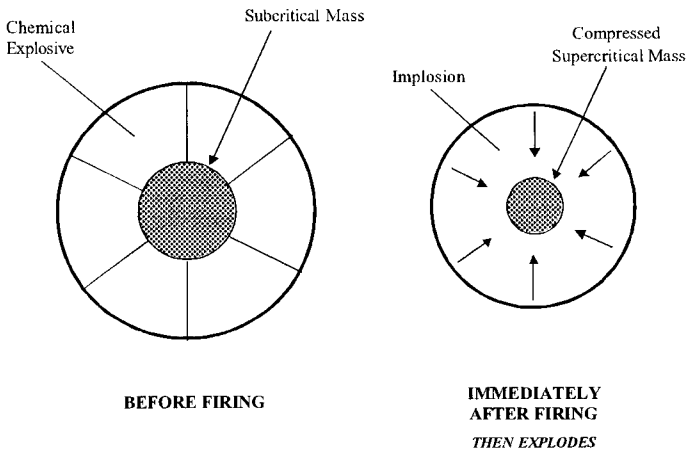



**Figure 3: Concepts of the Implosion-Assembled Atomic Weapon**

To develop and build implosion-assembled devices, much experimentation had to be done with getting chemical high explosives to precisely assemble something with great symmetry, in contrast to their typical uses in blowing things up. Work on high explosives centered on achieving microsecond timing of detonations at the surface of the explosive and use of "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 development of "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 Los Alamos' 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 Figure 4 (LANL, 1983).

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

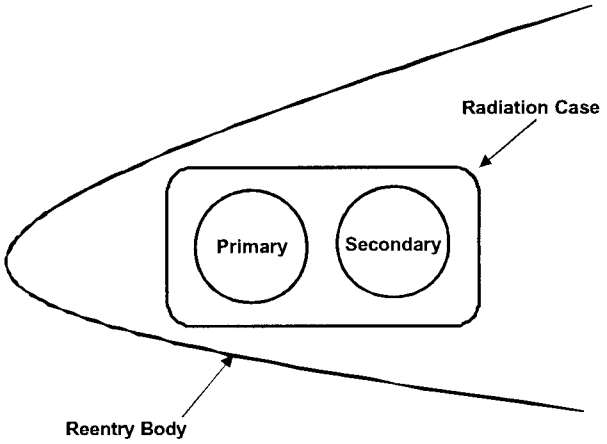



**Figure 4: Concepts of a Staged Nuclear Weapon**

After World War II, Los Alamos scientists and engineers were involved in development and testing of numerous designs of nuclear devices that were more and more powerful, compact, reliable, dependably deployable in the field, and contained in a variety of delivery vehicles suited to various combat objectives. They were involved in many tests of nuclear devices within the continental United States, in the Pacific, and in Alaska, including some that were part of the Plowshare program that 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, Los Alamos was 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, Los Alamos was called upon to perform special functions in its backup role. For example, because of an accident at the Hanford Plutonium Finishing Plant in 1984, plutonium was sent in oxide form to Los Alamos for conversion to metal (USDOE, 1997). Special activity at Los Alamos 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 development and production of the 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 nonmilitary development and fundamental research. For example, Los Alamos developed one of the largest experimental machine shops in the country. The 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 Los Alamos. 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 Los Alamos, and the plasma

thermocouple program explored methods for drect conversion of fission energy to electricity for propulsion of potential spacecraft application.

Operations at Los Alamos have taken place in land divisions called Technical Areas, or TAs. Table 1 contains a listing of these Technical Areas, including some that have been abandoned, some that were combined with other TAs, and some that were cancelled before they ever became operational. Figure 5 shows the locations of the modern-day Technical Areas, and Figure 6 presents a timeline of some selected operations and activities at (or related to) Los Alamos.

References:

LANL, 1983. "Nuclear Weapon Illustrations", Classification Bulletin No. 9. August.

Serber et al., 1992. "The Los Alamos Primer– The First Lectures on How to Build An Atomic Bomb." Contains an annotated version of report LA-1, "The Los Alamos Primer" (1943). University of California Press, Berkeley.

USDOE, 1997. "Linking Legacies– Connecting the Cold War Nuclear Weapons Production Processes To Their Environmental Consequences." DOE/EM-0319. U.S. Department of Energy, Washington, DC. January.

**Table 1: Los Alamos Technical Areas of the Past and Present**

| | |
|---|---|
| TA-0 | Los Alamos Townsite |
| TA-1 | Original Main Technical Area (not currently active): |
| TA-2 | Omega TA-3, Core Area: [a.k.a. "South Mesa Site"] |
| TA-4 | Alpha Site: Removed in 1956 |
| TA-5 | Beta Site: Former Firing Site |
| TA-6 | Two-Mile Mesa Site |
| TA-7 | Gomez Ranch Site. Abandoned in 1945. Former Firing Site. |
| TA-8 | GT Site (or Anchor Site West) |
| TA-9 | Anchor Site East |
| TA-10 | Bayo Canyon Site (not currently active; "removed in 1963" ) |
| TA-11 | K Site |
| TA-12 | L Site: |
| TA-13 | P Site: Incorporated with S Site (TA-16) |
| TA-14 | Q Site |
| TA-15 | R Site |
| TA-16 | S Site |
| TA-17 | X Site: Canceled |
| TA-18 | Pajarito Laboratory |
| TA-19 | East Gate Laboratory: Released to AEC in 1962 |
| TA-20 | Sandia Canyon Site: Abandoned in 1957. Former Firing Site. |
| TA-21 | DP Site |
| TA-22 | TD Site |
| TA-23 | NU Site: Removed in 1950 |
| TA-24 | T Site: Incorporated with S Site (TA-16) |
| TA-25 | V Site: Incorporated with S Site (TA-16) |
| TA-26 | D Site: Removed in 1966 |
| TA-27 | Gamma Site: Abandoned in 1945 |
| TA-28 | Magazine Area A |

**Table 1: Los Alamos Technical Areas of the Past and Present (continued)**

TA-29 Magazine Area B: Abandoned in 1957
TA-30 Electronics Test Area: Removed in 1945
TA-31 East Receiving Yard: Removed in 1954
TA-32 Medical Research Laboratory: Removed in 1954
TA-33 HP Site
TA-34 New Laboratory Warehouse Area: Canceled
TA-35 Ten Site
TA-36 Kappa Site:
TA-37 Magazine Area C
TA-38 Monte Rey Site: Canceled
TA-39 Ancho Canyon Site
TA-40 DF Site
TA-41 W Site
TA-42 Incinerator Site: Abandoned in 1970.
TA-43 Health Research Laboratory
TA-44 Los Angeles Shop: Abandoned in 1958
TA-45 Radioactive Liquid Waste Treatment Plant (not currently active):
TA-46 WA Site
TA-47 BR Site (Brunns Railhead in downtown Santa Fe). Abandoned in 1958.
TA-48 Radiochemistry Site
TA-49 Frijoles Mesa Site
TA-50 Waste Management Site
TA-51 Environmental Research Site
TA-52 Reactor Development Site
TA-53 Los Alamos Neutron Science Center
TA-54 Waste Disposal Site
TA-55 Plutonium Facility Site
TA-56 Subterrne Basalt Site. Abandoned 1976
TA-57 Fenton Hill Site
TA-58 Reserved for experimental sciences tied to programs currently located at TA-3.
TA-59 Occupational Health Site
TA-60 Sigma Mesa
TA-61 East Jemez Road
TA-62 Reserved for experiments, public/corporate interface, environmental research, buffer zones.
TA-63 A major growth area at the Laboratory, environmental and waste management functions.
TA-64 Central Guard Facility and headquarters for the Hazardous Materials Response Team.
TA-65 Technical Area not currently active or never assigned?
TA-66 This site is used for industrial partnership activities.
TA-67 This is a dynamic testing area that contains significant archeological sites.
TA-68 This is a dynamic testing area that contains archeological and environmental study areas.
TA-69 Undeveloped; serves as an environmental buffer for the dynamic testing area.
TA-70 Undeveloped; serves as an environmental buffer for the high-explosives test area.
TA-71 Undeveloped; serves as an environmental buffer for the high-explosives test area.
TA-72 This is the site of the Protective Forces Training Facility.
TA-73 This area is the Los Alamos Airport.
TA-74 Otowi Tract: contains archeological sites, an endangered species breeding area, water wells.

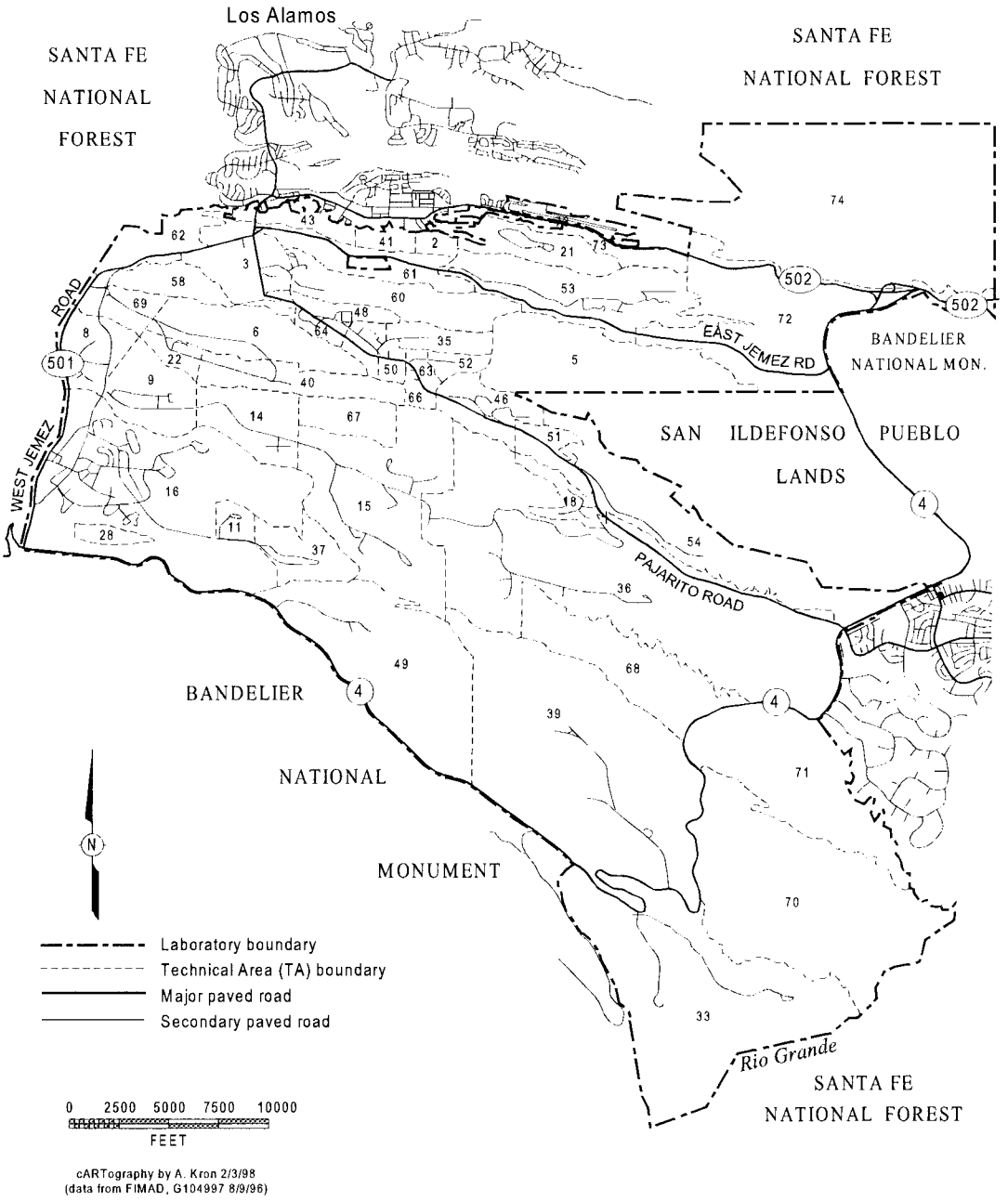
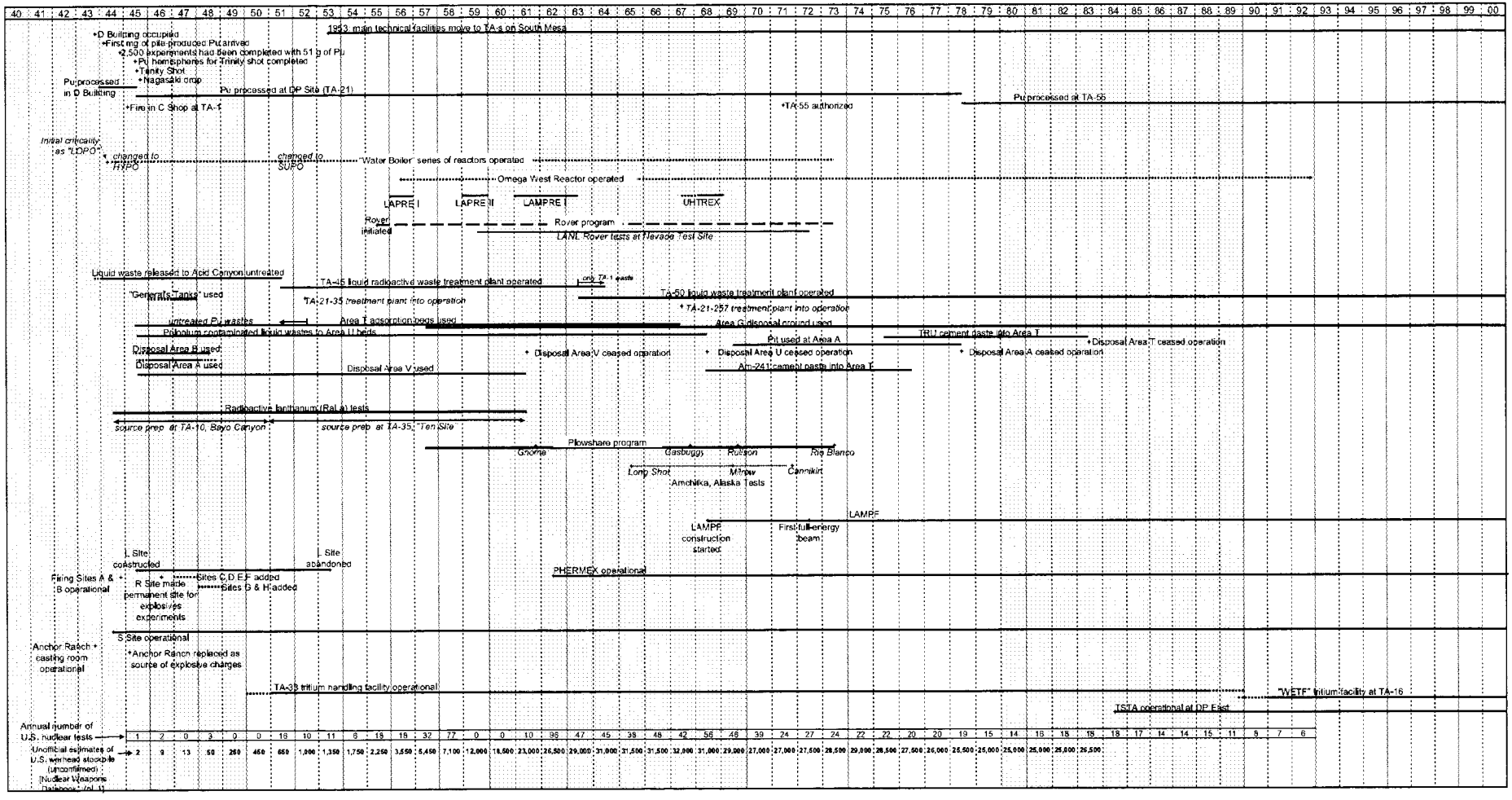



**Figure 5: Map of LANL technical areas and roads.**

*DRAFT* **FIGURE 6: TIMELINE OF SELECTED LOS ALAMOS OPERATIONS AND ACTIVITIES** *DRAFT*

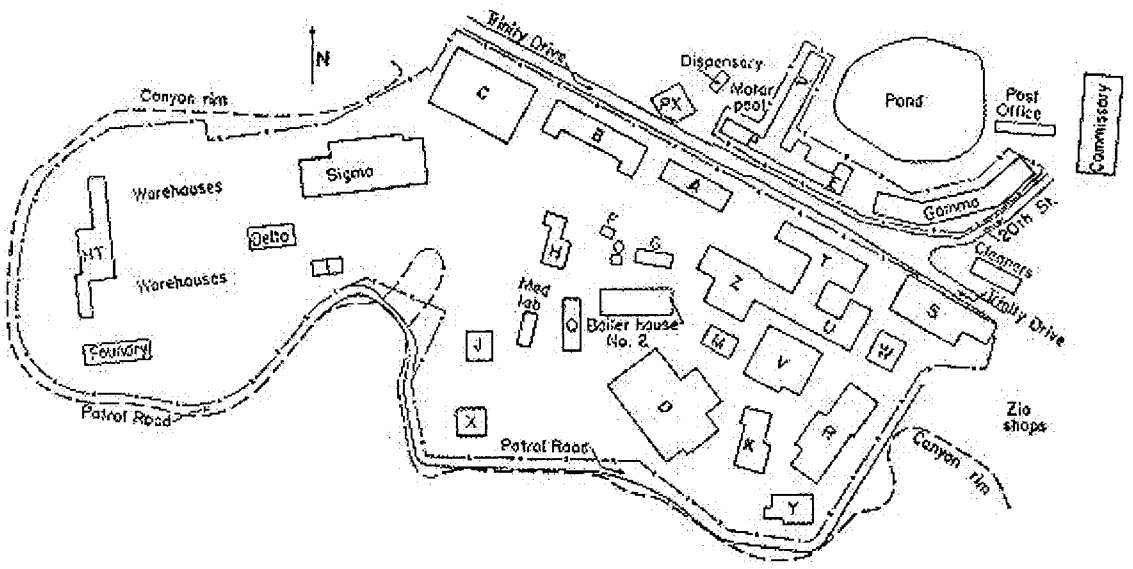


## 2.2 Processing of Plutonium

One of the important early roles of the Los Alamos laboratory was the processing of the newly created and largely unknown material plutonium. The assignments given to Los Alamos in the early 1940s were to:

- Perform the final purification of the plutonium received at Los Alamos,
- Reduce the plutonium to its metallic state,
- Determine the metal's relevant physical and metallurgical properties, and
- Develop the necessary weapon component fabrication technologies (Hammel, 1998).

Los Alamos was the first site in the world to receive quantities of plutonium large enough to manufacture weapon components. Plutonium processing was originally performed in TA-1, the original Los Alamos technical area that was located near Ashley Pond as shown in Figure 7.




Key to Selected Buildings:

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

**Figure 7: Map of the Original Technical Area, TA-1**

Early Plutonium Processing at TA-1

Facilities housing plutonium operations at TA-1 were as follows: [LA-6887; Ahlquist, Stoker, Trocki, 12/77]:

D Building- Plutonium chemistry, metallurgy, and processing were performed there. Significant amounts of $^{239}$Pu and $^{235}$U were processed. In August 1944, 10 mg of plutonium exploded in a chemist's face. D Building was demolished from March through November 1954.

D-2 Building- Contaminated laundry and glassware decontamination were performed there; drain lines emptied to an open area near the rim of Los Alamos Canyon. After the laundry moved to DP Site, this building was used as electronics repair shop and for decontamination of equipment (such as pumps) from D Building. Uranium was also present. Removed in October 1953.

D-5 Sigma Vault- Was used for storage of $^{239}$Pu and $^{235}$U. Demolished in December 1965.

ML Building- Housed the Medical laboratory, site of human uptake and excretion studies by H-4 and H-5 groups and urine assay. After H-4 and H-5 moved out, Group J-11 used the building for radiochemical processing of americium and curium.

In January 1945, a serious fire broke out in "one of the shops" at TA-1, namely C Building. This raised concerns about the possibility of a fire in D Building. This, 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 TA-21.

TA-21 (DP Site) Historical Operations- DP West

DP West was the location of the plutonium facilities that replaced the original plutonium facilities in Building D of TA-1. Most of these facilities were constructed in 1944-1945 from used warehouses. The necessary process equipment was installed during this time as well. Operations appeared to have started by the end of November 1945 (Rep. No. 139).

The primary functions of the facility were: 1) to produce metal and alloys of plutonium and other transuranic elements from nitrate solution feedstock; 2) to fabricate these metals into precision shapes; 3) to provide and install protective claddings; 4) to measure the chemical and physical properties of these metals and alloys; and 5) to permit recycling of scrap or materials used in experiments so that these materials could be reused rather than discarded (Rep. No. 2344).

In Figure 8, the early layout of DP West is shown with the main buildings (Rep. No. 2346). Buildings 2 and 3 housed wet chemistry processes, and Buildings 4 and 5 housed dry chemistry processes (LAB-CMR-12-60). Building 12 was the main filter building.

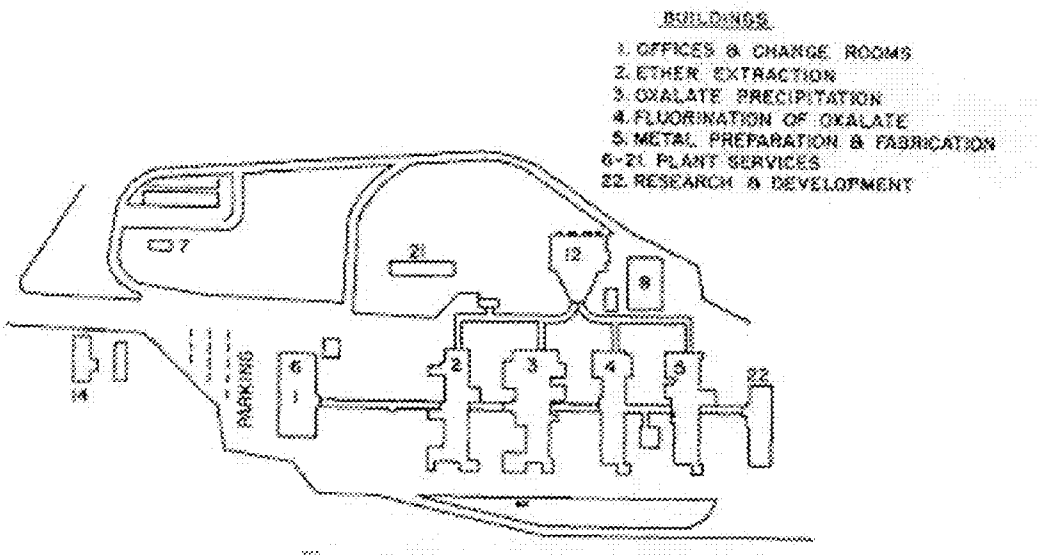



**Figure 8: Early DP West Layout**

Some of the major changes during the lifetime of the site are outlined below. This discussion is taken from *Los Alamos DP West Plutonium Facility Decontamination Project 1978 – 1981* (Rep. No. 2344).

- In 1949, plutonium gloveboxes were connected with short pass-through tunnels.
- In 1951, a semi-automated metal production line was put into operation. A facility was completed for recovering plutonium in dilute residues. Secondary containment rooms were constructed around potentially hazardous operations.
- In 1952, a liquid waste treatment plant was constructed, TA-21-35. A new treatment plant, TA-21-257, replaced the old plant which was decommissioned in 1968.
- In 1956, the plutonium metallurgical and metal fabrication systems were rebuilt. Conveyor tunnel systems were placed above the gloveboxes, allowing improved plutonium transfer capabilities and personnel passage under the tunnels.
- In 1959, a nuclear criticality alarm system based on detection of gamma radiation was installed. The process exhaust system was separated from the plant exhaust system. The new system included a high-efficiency filtration system located in TA-21-146.
- In 1963, a new plutonium fuels development building, TA-21-150, was constructed.
- In 1967, a new liquid waste treatment plant, TA-21-257, was constructed.
- In 1968, personnel corridors between major buildings were converted to ventilated air locks.
- In 1971, new room exhaust air systems were installed in plutonium areas and utility services were upgraded.
- In 1973, the exhaust filter building, TA-21-12, was decommissioned after having been abandoned in 1959.
- In 1974, a wet pipe sprinkler system was installed throughout the plutonium processing buildings.
- In 1977, the transfer of equipment to the new Plutonium Facility at TA-55 began.
- In 1981, decontamination was completed and the areas were transferred to new tenants. Decontamination began in 1978.

The following were considered Major Decommissioning Activities conducted within the Los Alamos Environmental Restoration project (Site-Wide EIS, DOE/EIS-0238, January 1999).

- "Demolition of a plutonium filter facility" completed in 1975 [ TA-21-12]
- "Decommissioning of an actinium-contaminated filter building" completed in 1981 [TA-21-153]
- "Decontamination of plutonium facility at DP West" completed in 1982

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

Building 2 (TA-21-2)

Building 2 housed numerous gloveboxes used for dissolution and recovery of plutonium and storage of $^{241}$Am wastes. The building also housed a scrap incinerator, solvent extraction columns, and a liquid-waste loading area.

On December 30, 1958, an accident occurred in Building 2 South involving separated phases in a plutonium process tank, under unshielded operation. The operator (Cecil Kelley) died 36 h later.

Building 3 (TA-21-3)

Housed oxalate precipitation operations. No additional information concerning Building 3 operations has been found at this time.

Building 4 (TA-21-4)

Building 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 the examination of 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 (Rep. No. 2344). Rooms 403, 404, 405, 406, and 407 also had gloveboxes that were used for Pu-239 and Pu-238 metal preparation during these early years.

Building 5 (TA-21-5)

Building 5 was the plutonium metal fabrication facility. Work centered around the production of plutonium metal and metal alloys and the fabrication of precision plutonium parts for nuclear devices. In 1963, Room 506 was constructed to house electro-refining equipment needed to produce high purity plutonium metal. Also added in 1963, Room 500A housed an air-drying system for air supplied to the conveyor tunnels and gloveboxes. In 1964, Rooms 530-534 were added to provide additional fabrication and testing facilities (Rep. No. 2344).

Until 1974, all work in Building 5 was with $^{239}$Pu for the weapons program. In 1975, $^{238}$Pu was introduced into one glovebox line in Room 500 for limited research work on testing HEPA filters.

A fire broke out in a plutonium contaminated CWS exhaust filter in Room 501, DP West on 7/15/59. Sparks from welding of an exhaust duct started it. The fire reportedly did not spread to the main filter house. Fans of the main filter house were turned off, as were room air intake fans. Highest stack sample (8-h average from Stack #1) read 15,067 dpm/m$^3$. [Repository No. 240]

Building 12 (TA-21-12)

Building 12 was the filter building that was put into service in May 1945. The plutonium process buildings, Buildings 2, 3, 4, and 5, were ventilated with a 60,000 $m^3$/min central air exhaust system. This system handled air from rooms and fume hoods, sparging of dissolvers, and venting of solution tanks. At that time it was not believed necessary to exhaust the air from the gloveboxes, but several years later gloveboxes were vented. This air was exhausted, without filtering, through the room air exhaust system. Electrostatic precipitators backed up by a single bank of American Air Filter Company type PL-24 filters removed the particulates from the exhaust air. This system was considered the best available for air cleaning at that time (Rep. No. 2349).

Building 12 continued in service for room and process air until July 1, 1959. In that year, another system was installed for the process air, and Building 12 then handled only room air. Building 12 continued in service until February 1973, when new room air filtration systems were completed, one for each process building (Rep. No. 2349). Building 12 had four stacks.

Building 21 (TA-21-21)

Building 21 was the old vault that stored produced uranium and plutonium metal.

Building 33 (TA-21-33)

Building 33 housed research efforts into collecting additional plutonium from waste streams.

Building 150 (TA-21-150)

Building 150 was built in 1963 as a plutonium fuels development building (Rep. No. 2344). The building was built next to Building 5.

Some of the programs the building supported included: 1) the development of Pu-238 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 Pu-238 fuels for isotopic powered heat sources for powering artificial organs (Rep. No. 2344).

In an incident in DP West Building 150, on 10/7/70, a sealed capillary broke, resulting in the release of a reported 10 ug of $^{238}$Pu up a vent. Estimated to be 2800 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 E-14 μCi/mL $^{238}$Pu (at housing near the runway) and 0.29 E-14 μCi/mL $^{239}$Pu (DP fence). [10/14/70 memo from Wm. R. Kennedy to George L. Voelz, Health Div. Leader; See repository nos. 246 and 247]

Building 210 (TA-21-210)

Building 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. This system was considered the best available for air cleaning at that time (Rep. 2349). The air was finally discharged by exhaust fans out of four 57-foot stacks.

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. Filter Queens sampled the exhaust air at these locations.

More Recent Plutonium Processing

In 1969, the decision was made to build a new facility, TA-55, the Plutonium Facility Site. Processing of plutonium and research on plutonium metallurgy are done at this site, which is also known as "PF Site." Includes processing and recovery of Pu-239 from scrap materials, recycle, metal production, metal fabrication, and R&D. This is the site of special isotope separation research. The SIS-III was designed to provide special plutonium isotopes for LANL weapons research. The site also has responsibility for manufacturing heat sources for weapons-related programs. [Nuclear Weapons Databook, Vol. III]

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). Was constructed around 1951-52. Wing 9 was constructed in 1961. |
| TA-3-32 | Cryogenics |
| TA-3-34 | Cryogenics |
| TA-3-35 | Press Building [Rep. No. 175 describes operations here with uranium & graphite] |
| TA-3-39 | Tech 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 Rep. No. 225, c. 1981) |
| 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.

Stacks from areas other than Wing 9 emitted an average concentration of 1.5 pCi/m$^3$ and a maximum of 9 pCi/m$^3$. The total daily output from all stacks is 18 uCi of total alpha emitters. For Wing 9, alpha contamination was below detectable levels and beta was < 0.5 pCi/m$^3$. Average daily iodine emission was 20 pCi/m$^3$. [Repos. No. 113].

Wing 3 has no HEPA filtration, while some other wings have it. [Repos. No. 711]. Unclear how they determined what went into HEPA filtered space. Stack FE-19 has experienced elevated releases; see Repos No. 835; 1.252 μCi of $^{239}$Pu was released. As of 10/95, Fe-19 had Aerosolve-95 filtration. Was installed ~8 y ago and was 90% efficient. Tests in January 1995 showed that efficiency had decreased to ~60%. [Repos. No. 835].

FE-19 serves the glove box processes and rooms on the south side of Wing 3. As of March 1980, had a demister, one stage of M-80 prefilters, and one stage of American Air Filter Continental 2000 filters (i.e., bag filters; published 85% efficient for 0.3 um DOP). Had Aerosolve 95 filters instead prior to July 1976.

Since early 1974, FE-19 has been major source of plutonium at LASL (up to 99%of total in 1980). Releases from FE-19 began to increase during Feb 79, when two filters tore. During filter change-out, flow reversal sent 143 μCi of Pu up FE-20 stack. [Repos. No. 512] February 1980 testing showed FE-19 filters only 29.3% efficient. The release from FE-19 from Jan 19 – Jan 26, 1979 was 91 μCi, which is greater than the total release for this stack in 1978.

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

## 2.3 Processing of Uranium

Facilities at TA-1 housing uranium operations included:

C Building- Uranium machining (a normal machine shop with a uranium machine shop in southeast section). Became operational in October 1943. Roof caught fire the night of January 18, 1945 and was rebuilt; provided incentive for a safer D Bldg. Removed 12/64.

G Building- Housed the uranium and graphite "Sigma Pile"; leak-testing of radium sources. Removed 6/59.

HT Building- Heat treatment and machining of normal and enriched uranium (Shops Department). Removed in 12/65. Very large castings were handled.

HT Barrel House- Storage of $^{239}$Pu and $^{235}$U. Demolished 7/64.

M Building- Processing, metallurgy, and recovery of enriched uranium.

Sigma Bldg- Casting, machining, powder metallurgy of normal and enriched uranium, thorium (eastern part was normal; western part was enriched). Demolished 12/65.

TU Building- Machining of normal uranium (tuballoy). Removed in 1964.

TU-1 Building- Recovery of enriched uranium, storage. "Furnace" for burning rags, etc. Removed 7/64.

V Building- The original machine shop; some uranium and beryllium machined there. Also handled unusual assignments such as welding thin stainless steel into envelopes and machining and grinding tungsten carbide. Volume of work increased through 1943 and 1944 to about 10,000 man-hours per month, nearly double the design load. A second shop, C Shop, was completed in October 1943. V Building was removed 2/59.

The Sigma Complex in in TA-3 housed large-scale metallurgy and fabrication of normal and fully enriched uranium. Air from areas for casting and machining enriched uranium was filtered through Aerosolve 95 filters. Air from areas handling enriched uranium in powder form is filtered through bag filters. [Repository No. 113]

## 2.4 Processing of Other Metals

TA-1 Facilities housing fission-product operations included:

J-2 Building- Used by Group J-2 for radiochemistry work on weapons test debris, processing of plutonium. Uranium also present. $^{239}Pu$, $^{235}U$, $^{238}U$.

H Building- Radiochemical and radioactive tracer processing. Initially used for work with $^{210}Po$ (source preparation), later used by CMR-10 for office and work space. Some $^{140}Ba/^{140}La/^{90}Sr$ contamination. Demolished in 1957.

Gamma Building- $^{210}Po$, $^{137}Cs$; a $^{137}Cs$ contamination incident occurred. Removed 2/59. Practice assembly of the high explosives (HE) for the first bomb was done here or in the Gamma 1 Building.

Gamma 1 Building- the "Ice House"; $^{239}Pu$ and $^{235}U$ assembly and storage. Removed 2/59.

TA–1 Facilities housing radium operations included:

O Building- Storage of sealed radium and radium/beryllium sources; some leaked. In front of building, radon was cooked off radium sources on a hot plate before resoldering. Demolished 11/56.

Q Building- Used by medical and health-monitoring group. Some film calibration operations with $^{226}Ra$ sources; a spill occurred. Building removed 2/59.

TA–1 Facilities housing operations with other materials included:

I Building- Used for machining beryllium. Sold to Dog Obedience Club in 1958 and moved to Airport Road. Found to be contaminated with nonradioactive beryllium, so demolished in 1959.

D-1 Building- Calcium metal storage. Moved to TA-21 in 1946. (Calcium metal was the reducing agent for green salt, $UO_2$ ).

D-7 Building- CMR HF gas analysis. (HF was used in converting $UO_2$ to $UF_4$)

FP Building- Foundry for nonradioactive, nonferrous metals. Removed 4/65.

R Building- Glass shop, cryogenics, model shop, carpenter shop.

Saw Building- Sawing of graphite. Removed 2/53.

T-1 Bldg- Original Administration Building

W Building- Van de Graaff accelerator. Uranium, Po-210, tritium.

X Building- Cyclotron. Some radioactive targets used.

Y Building- Physics laboratory. Tritium, uranium, etc.

Z Building- Cockcroft-Walton accelerator.

M-1 Building- Originally used for machining lithium, later for $^{238}U$ samples.

K-1 Building- Machining of graphite.

Repository Document No. 124, from late 1952, reported that "The filters in M-1 bldg had become excessively loaded with lithium hydride and have now been changed. Arsenic will soon be incorporated into the lithium hydride. Fabrication operations on lithium hydride and arsenic in Sigma Building are being followed closely."

Building W had 2 high-voltage electrostatic generators used to produce variable energy neutrons for cross-section measurements. Protons were accelerated, hit a target (usually lithium), producing neutrons. Some X rays also produced, and there were hazards from neutrons and X rays.

As of July 1945, in the Foundry in "R" shop, several tons of lead were melted and poured a month without adequate hoods, fans, or roof or window ventilation. When high explosives molds were cleaned there, persons often became ill from the vapors. "The personnel have not been placed among the persons exposed to hazardous materials, although "metal fume fever" is a constant source of danger there." [7/17/45 memo from J.H. Allen to L.H. Hempelmann re: Health conditions in the Foundry]

## 2.5 Tritium Operations

Building 155 at DP East most recently housed the Tritium Systems Test Assembly (TSTA), which conducted research for developing and demonstrating effective technology for handling and processing deuterium and tritium fuels for use in fusion reactors.

As of April 1990, TSTA had operated for 70 months. Throughput totaled >10 billion Ci; the maximum inventory was 1,300,000 Ci; and stack releases were reportedly 110 Ci. Monthly releases from TSTA stack for Jan 1985 thru June 1990 are given in Repository No. 242, in Ci of HTO and Ci of HT and totals.

An equipment failure in the CMB-3 tritium facility resulted in the release of ~13.8 Ci of $^3H$ from the DP East Bldg 209 stack FE-10 from 4/11/81 thru 4/14/81. The highest daily average was 57.5 times the MPC for tritium oxide. [Repository No. 235]

"An enormous amount" of $^3H$ went up the stack from this "tritium filling" facility at TA-33 per Neely/Elliott [12/98 tour]. Used alumina sieves; once saw a puddle of $^3H$ on the floor. It has been reported that gram quantities were released over decades. These quantities reportedly dwarf the $^3H$ used in accelerators at LANL. They did pressurized filling of $^3H$ containers at TA-33 from the early 1950s to the late 1980s. This facility was replaced by the WETF facility at TA-16. Hot cells here opened to the environment (no double containment). Oil served as infinite sink for tritium (e.g. in vacuum pumps). There is a tritium outfall from this facility. TA-33 also has some firing points; can find depleted uranium on the ground. "The people just turned off the lights and left" this facility.

Research at TA-33 released the largest amount of airborne tritium from routine LASL operations. Releases in 1978 were considerably higher than previous years. From 1973 to 1977, the average routine release of tritium gas from TA-33 was 3050 Ci (range 615 to 5916 Ci). An accidental release of 30,800 Ci occurred on October 6, 1977. The total for 1977 was 615 Ci, not including the accidental release. Releases in 1978 totaled 17,780 Ci (1.85 g), which represents 95% of all routine tritium releases at LASL in 1978. A new replacement facility was proposed for funding; it would have been at TA-41 and would have a system that captures and recycles tritium, limiting routine releases. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" circa Oct. 1979].

Whenever firing experiments proposed by GMX Division would result in the release of >100 Ci of tritium in a single shot or would raise the annual total above 5000 Ci, set up a system for review by GMX and H Division leaders. Prior to this policy, used about 180 Ci per shot and had no annual total. Only one year 1967-1971 would have exceeded 5000 Ci. [3/24/72 memo E.H. Eyster to D.P. MacDougal, Subject="Release of Tritium in GMX Shots."]

The WETF facility at TA-16 replaced the tritium facility at TA-33 (after TA-41 was considered but rejected as a replacement site).

The construction proposal for the Target Fabrication Facility at TA-35 says: "The facility (called the TFF) will make targets in support of the laser fusion target experimental program that will use Helios, a 10-kJ eight beam $CO_2$ laser system that recently achieved full operational status, and Antares (High Energy Gas Laser Facility), the 100-kJ $CO_2$ laser system now under construction. Special laboratories for filling laser-fusion targets with deuterium-fusion gas in tritium-handling dry boxes. Also laboratories for development of cryogenic targets. The tritium facility was designed to be a "zero release" system, with secondary containment dry boxes, an air scrubbing line, cryogenic handling capability, and a stack for accidental release protection."

On 24 May 1977, there was a release of up to 800 Ci of tritium from the Van De Graaff accelerator [Repos. Nos. 593, 829]. On May 25, 1979, 3,000 Ci of tritium (probably as oxide) was released at roof level from SM-34 cryogenics area [Repos. No. 594].

## 2.6 Polonium Operations

Polonium was used in initiators, utilizing the ($\alpha$,n) reaction of $^{210}$Po and $^{9}$Be. In February 1945, schedule for polonium delivery from Monsanto [to TA-1] was increased to 100 Ci per month by June and 500 Ci per month by December [Hoddeson et al. 1993]. At TA-1, polonium was handles in H Building and Gamma Building.

DP East began operation in September 1945 and contained buildings 151, 152, and 153. Building 155 was completed in December 1949. These buildings were used to process polonium and actinium and to produce initiators. Building 209 was built in 1964 to house research efforts in high-temperature and actinide chemistry. Bldg 155 most recently housed the Tritium Systems Test Assembly (TSTA), which conducted research for developing and demonstrating effective technology for handling and processing deuterium and tritium fuels for use in fusion reactors.

It is reported that "the well-designed DP polonium plant went into operation sooner than did the Pu plant." [TR 6704, Box 6 of 8].

A building similar to TA-21-12 was Building 153 at DP East. This building exhausted the air from several buildings at DP East and was determined to have been constructed similarly to Bldg. 12 (Rep. No. 2343). Bldg. 153 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. There were two blowers and two stacks.

## 2.7 Operations Involving Radioactive Lanthanum (RaLa)

TA-10, Bayo Canyon Site, was used between 1944 and 1961 for a set of experiments using conventional high explosives, radioactive lanthanum (RaLa), and depleted or natural uranium for implosion diagnostics. A total of 254 of these "hydrodynamic tests" or "hydrotests" were done, 71 by the end of 1946 (See Table 2). The shots used RaLa sources ranging in size from ~25 Ci to 7090 Ci (Dummer et al., 1996 [LA-13044-H]). 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. Radiochemical operations conducted at the site resulted in the generation of liquid and solid radioactive wastes, which were disposed of in subsurface pits and leaching fields. The site was decommissioned by 1963 and transferred to Los Alamos County on 7/1/67. [DOE/EV-0005/15, UC-71, June 1979; Rad. Survey of Bayo Canyon].

**Table 2: Quantities of Radioactive Lanthanum Used**

| Year | Curies of RaLa Used in Bayo Canyon Shots | 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 Curies | 254 Shots |

During the 18 years of the RaLa series of experiments in Bayo Canyon, about 226 millicuries of $^{90}Sr$ was reportedly released; over 80% of the 226 mCi was released in seven shots in 1945 (Dummer et al., 1996 [LA-13044-H]). In a dose assessment conducted by LANL personnel, the highest annual dose from the RaLa shots (17 millirem) was calculated to have occurred in 1955; if an individual had been in Los Alamos throughout all of the experiments, the calculated dose to that hypothetical individual would have been approximately 110 millirem (Dummer et al., 1996 [LA-13044-H]).

The RaLa sources were prepared at the TA-10 Chemical Process Building from 1944 to 1950. This function moved to the TA-35 "Ten-Site" facility for 1951-1963). The name of the site is likely tied to this TA-10 connection, and/or to the operating group, CMR-10.

CMR-10 group relocated to Ten-Site (TA-35) some time between April 1950 and December 1950. [12/27/50 memo C.M. Perry of H Div to R. Phillip Hammond of CMR-10 re: "Ten-Site Maximum Permissible Dose Limits." They had been given special permission in early 1950 to raise the worker dose limit at TA-10 to 0.6 r gamma over a two-week period. Once located at TA-35, the limit was set back to 0.3 r/2 wk.

The Chemical Processing Plant in Idaho became the source of purified $^{140}Ba$ in 1956, and a typical shipment was about 40,000 Ci $^{140}Ba$. The $^{140}La$ sources prepared at Ten Site were usually in the range of 2,000 to 4,000 Ci. Almost 2 million Ci of $^{140}Ba$ had been handled at Ten Site by 1963 when the RaLa program was terminated. [LA-UR-79-3091]

Results of a resurvey of the area show that residual surface contamination of $^{90}Sr$ in Bayo Canyon averaged 1.4 pCi/g, or approximately 3 times the levels attributable to worldwide fallout. DOE

calculations show individual consuming 50 kg/y of vegetables and fruits grown in the contaminated soil of Bayo Canyon would reportedly receive a 50-year dose of about 46 mrem to the bone, which is 3% of the guides and 25% of annual exposure from natural radiation in the Canyon. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" c. Oct. 1979]

The [TA-35] RaLa cell and control room have been completely dismantled. [Jun 21 thru Jul 20, 1964; Repository No. 72]

## 2.8 Explosives At Los Alamos National Laboratory

Research, development, and testing of high explosives were conducted at more than 25 different Technical Areas of LANL (Goldie 1984; LANL 1990). 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 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 it became clear in July 1944 that the weapon would have to be an implosion design due to the presence of the plutonium-240 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 started as the concern of one small group and grew into the Laboratory's major problem in the early 1940s. The first implosion tests at Los Alamos were made 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 indicated 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 needed. Construction of the casting plant was begun 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), because finding men with experience in handling explosives was nearly impossible (Hawkins et al. 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 the use of explosive lenses that would convert a multiple-point detonation into a converging spherical detonation wave thus eliminating troublesome interaction. The design of 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 explosives and their fabrication and to set up a production system. 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. Investigation of implosion dynamics and design of the active core were given to the Weapon Physics (G) Division (Hawkins et al. 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 rejected for quality control reasons. The principal types of HE used were Composition B, Torpex, Pentolite, Baranol and Baratol. The use of 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 et al. 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, and 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 whose shape was determined by theoretical calculations. The initial facilities at S-Site were inadequate especially for machining. As a result, there was continuous planning and construction of new buildings until just before the Trinity test in July 1945. Casting operations in Building 42 used stainless steel candy kettles, 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 supported in the steel weldment. In Wilder's opinion, development of the explosive component of the bomb was greatly facilitated by the use of self-adhesive tape just about everywhere. 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 later water was used. 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. 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, in Buildings 519 and 520. Practice assemblies were made in Gamma Building in the main Tech Area. 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 where Building 260 was located (Wilder 1973).

According to Hawkins et al. (1961), S-Site at its peak used over 100,000 pounds of high explosives per month. G. Kistiakowsky's recollection was that about 25 tons (50,000 pounds) 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 pounds 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 22). 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 pounds. (One gram of HE will reportedly 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 development and testing of explosives since 1944. HMX and metals were identified in Q-site soils (Harris 1993). RCRA Facility Investigation plans for OU-1082 (S-Site) and OU-1086 (R-Site)

Sites in the vicinity of TA-16 (S-Site) formerly used in the 1940s 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 or are still active. 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 was more recently used for drop tests to study impact initiation of explosives. The resulting debris in the immediate vicinity of the drop tower is picked up and removed for disposal 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 2 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 have been expended at these two firing sites. Hazardous materials, including uranium, beryllium and lead, have largely been left in place at these sites where the materials were deposited by the explosion. Other materials that may have been deposited 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 (LANL 1993).

Other Uses of Explosives at LANL

During the VJ Day celebration at the Laboratory, Kistiakowsky reportedly borrowed a military jeep with a driver and gave the LANL scientists a "21-gun salute" by detonating 21 boxes of Comp B explosive, although someone attending the party said there were actually 22 explosions. It was also reported that the Pajarito ski hill was cleared of trees using plastic explosives (Kistiakowsky 1975).

Key Facilities for High Explosives at Los Alamos

S Site (TA-16) was initially called Sawmill Site, after a portable sawmill that had been erected on the site, and left huge piles of sawdust behind. Its name was shortened to S Site. [Martin 1998].

Investigations at S Site have included development, engineering design, prototype manufacture, and environmental testing of nuclear weapons warhead systems. TA-16 is the site of the Weapons Engineering Tritium Facility for tritium handled in glove boxes. Development and testing of high explosives, plastics, and adhesives, and research on process development for manufacture of items using these and other materials are accomplished in extensive facilities.

Facilities include a slurry plant with a capacity of 300 lbs of explosive per batch [Nuclear Weapons Databook Vol. III]. The material being cast was a two-phased slurry consisting of a dense solid phase dispersed in molten TNT. [Hoddeson et al. 1993] At first Torpex was used, then PTX-2 (Picatinny ternary explosive 2), Comp B, Pentolite, Baranol, 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 whose shape was determined by theoretical calculations. Early castings were worked with hand tools, saws, rasps, and planes, to a template. HE compounds included Comp. B, TNT, and Baratol.

Early explosives processing facilities included:

| | |
|---|---|
| S-24 | (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 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 | were built at same time to machine Baratol and Comp. B castings from Building 27. |
| 94 thru 98 | were 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 being done was considered too dangerous to be performed at TA-1, so these operations were placed at remote locations. Alpha Site at TA-4 was used as a firing site for high explosives (HE). It was originally used to fire several charges per day of up to 1000 pounds 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 for studying implosions. Larger charges could be safely used at TA-5, and shots of several hundred pounds were used. S-Site at TA-16 was developed for production of HE to be used in the various tests. [LA-UR-97-4765]

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 probably 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 made into a permanent location for explosives experiments related to nuclear weapons design, involving experiments with up to 3/4 tons of HE. By 1947, Firing Sites C,D,E, and F were in use. In 1948, 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 these firing sites have been decommissioned and dismantled. The hazardous materials used in these explosives tests, e.g. U, Be, and Pb, have largely been left in place at the firing sites where the materials were 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, Cd, gold, and H-3. Many types of HE were used. While they may have left some residues, no unexploded HEs have been found in the analyses of site soils. Site E-F was most heavily used and reportedly contains the largest quantities of hazardous materials. Up to 72 tons of U and approx 800 lb of Be 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, "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) is being constructed. This site is also used for the investigation of weapons functioning and systems behavior in non-nuclear tests, principally through electronic recordings.

TA-9, Anchor Site East: At this site, fabrication feasibility and physical properties of explosives are explored. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied. Name refers to Anchor Ranch, a small cattle operation that was in the area when the MED took it over in 1943. "Active" per 10/2/84 memo from R. Goldie to D. Pinyan; subject was "Areas Containing or Contaminated by Explosives."

TA-14, Q Site: This dynamic testing site is used for running various tests on relatively small explosive charges for fragment impact tests, explosives sensitivities, and thermal responses. "Active" per 10/2/84 memo from R. Goldie to D. Pinyan; subject was "Areas Containing or Contaminated by Explosives."

## 2.9 Nuclear Weapon Component Design and Testing

Each year kilogram quantities of uranium are utilized in dynamic testing at LASL with an estimated 10% (based on limited measurements) being aerosolized. An estimated 35,000 to 45,000 kg of natural uranium and 40,000 to 50,000 kg of depleted uranium have been expended during conventional explosive tests at several LASL testing sites during 1949-1970. In 1978, 1371 kg of depleted uranium were expended in dynamic testing at LASL. These amounts reportedly do not go far beyond the test pad. Approximate dispersion calculations indicate that resulting airborne uranium concentrations at site boundaries from testing at LASL would be in the same range as attributable to natural crustal abundance uranium in resuspended dust. Individual stations with higher annual averages and maximum values are all located in dusty area where higher filter dust loading accounts for the collection of more natural uranium. Ecological studies have shown that of the uranium on the ground, only minor amounts (<0.1%) have moved an appreciable distance from the test areas and have no effect on animal and plant life. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" circa Oct. 1979].

The larger shots were "weapon simulating shots." H Division personnel asked for reporting of shots involving D-38 (depleted uranium, including niobium alloy), lead, H-3, beryllium; also cadmium, mercury, thorium. [4/22/71 memo E.H. Eyster to G.L. Voelz, Subject= Environmental Reports--'Toxic' Materials"]

Whenever firing experiments proposed by GMX Division would result in the release of >100 Ci of tritium in a single shot or would raise the annual total above 5000 Ci, set up a system for review by GMX and H Division leaders. Prior to this policy, used about 180 Ci per shot and had no annual total. Only one year 1967-1971 would have exceeded 5000 Ci. [3/24/72 memo E.H. Eyster to D.P. MacDougal, Subject="Release of Tritium in GMX Shots."]

There are some concerns about dangers of a one-point detonation of a nuclear device in Building 410 at S-Site. The accident scenario assumes that a one-point detonation releases 300 Ci (alpha activity) of weapons grade plutonium to the environment resulting in 650 acres being contaminated to <0.2 microCi/$m^2$ ["Potential Environmental Issues at Los Alamos Scientific Laboratory" c. Oct. 1979].

"Confined Pu Shots" were performed at TA-15 per Repository No. 225 (c. 1981). Flash x-ray confinement shots were performed at TA-15's R204 Firing Pad. They involved $^{239}$Pu and depleted uranium ("DU-238"). A potentially hazardous condition identified and analyzed is a failure of the confinement vessel.

TA-8, GT Site (or Anchor Site West): This is a dynamic testing site operated as a service facility for the entire Laboratory. It maintains capability in all modern nondestructive testing techniques for ensuring quality of material, ranging from test weapons components to high-pressure dies and molds. Principal tools include radiographic techniques (x-ray machines with potentials up to 1,000,000 V and a 24-MeV betatron), radioisotope techniques, ultrasonic and penetrant testing, and electromagnetic test methods.

TA-8 is "Active" per 10/2/84 memo from R. Goldie to D. Pinyan; subject was "Areas Containing or Contaminated by Explosives." Non-destructive testing of fuel elements, weapons components and other parts, including explosives. Involves Pu-238, Pu-239, U-235, U-238, Be, C0-60 sources up to 500 Ci, Ir-192 sources up to 100 Ci, Cs-137 sources up to 30 Ci, HE detonators. [Repository No. 226].

TA-15, "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. PHERMEX, which was the world's highest intensity x-ray facility, was completed in 1962 as a diagnostic tool to study implosion. PHERMEX sends X rays through an imploding mockup of a weapons assembly and provides researchers with detailed snapshots of the locations and configurations of implosion systems. Also used to study fluid dynamics and the behavior of matter under extreme conditions [Dateline: Los Alamos 1995 Special Issue] TA-15 is also the site where DARHT (the dual-axis radiographic hydrotest facility) is being constructed. DARHT is intended to replace PHERMEX. This site is also used for the investigation of weapons functioning and systems behavior in non-nuclear tests, principally through electronic recordings.

TA-14, Q Site: This dynamic testing site is used for running various tests on relatively small explosive charges for fragment impact tests, explosives sensitivities, and thermal responses. "Active" per 10/2/84 memo from R. Goldie to D. Pinyan; subject was "Areas Containing or Contaminated by Explosives."

TA-11, K Site: Facilities are located here for testing explosives components and systems, including vibration testing and drop testing, under a variety of extreme physical environments. The facilities are arranged so that testing may be controlled and observed remotely and so that devices containing explosives or radioactive materials, as well as those containing nonhazardous materials, may be tested.

"Active" per 10/2/84 memo from R. Goldie to D. Pinyan; subject was "Areas Containing or Contaminated by Explosives." As of 10/10/47, K Site had a 20-MeV betatron and a 500-mCi radium-beryllium source. [Memo H.O. Whipple to Hempelmann; subject="Inspection of K and T Sites, October 9, 1947"]

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## 2.10 Nuclear Device Testing

The Unites States has conducted a total of 1,054 nuclear tests, including 24 joint U.S.-United Kingdom tests. These tests have been conducted for several purposes (USDOE, 1997):

- 891 detonations were primarily to prove that a weapon or device would function as designed, to advance weapon design, or to verify the reliability of weapons in the stockpile;
- 100 detonations were chiefly to explore the effects of nuclear weapons;
- 88 were safety experiments;
- 4 were storage- and transportation-related experiments;
- 24 were joint U.S.-United Kingdom detonations;
- 7 were detonations to develop ways to detect nuclear explosions from a great distance; and
- 35 detonations explored nonmilitary uses of nuclear explosives (some tests included multiple detonations).

In the summer of 1957, the U.S. Atomic Energy Commission (AEC) formally established the Plowshare program to explore peaceful uses of nuclear explosives [Gerger et al., 1966]. There were 27 Plowshare tests and 35 detonations; in other words, some tests involved the detonation of multiple nuclear devices. Plowshare was a series of tests to explore the feasibility of using nuclear explosions for excavation, for stimulating the production of natural gas from marginal fields, and for other peaceful uses.

The project began with detonation Gnome on December 10, 1961, in Carlsbad, NM, and concluded with Rio Blanco on May 17, 1973, in Rifle, CO. [12/97 fact sheet obtained 7/99 from DOE Web Site].

In late 1968, LASL was informed by AEC that LASL involvement in two upcoming Plowshare shots had been approved. They were to be at Rulison Field, not far from Grand Junction, CO (a gas stimulation type) and SLOOP (a copper ore shot in southern Arizona. The first shot, probably at Rulison Field, was expected in the first half of 1969. LASL responsibilities would presumably include furnishing the nuclear device, emplacing it, stemming, and firing. J and W divisions were expected to be involved. [Repository No. 456]

Gnome was conducted 35 mi southeast of Carlsbad, NM (Kuran, 1999). It had many goals, including:

- Experimentation in the production of heavy isotopes, in much larger quantities than could be done economically in laboratories or in reactors.
- Research into the possibility of generating electricity by pumping water into the cavity after the detonation. The heat from the detonation would turn the water into steam, which would be piped out to drive a turbine generator.
- Conduct of seismic studies on how the geology around the detonation site behaves.

In the Gnome test, the nuclear device was lowered in a shaft to a depth of 1,184 feet. The energy from the 3.0 kiloton shot immediately vaporized 100 tons of rock salt bedded at the point of detonation. The shot created a huge underground cavern approximately 175 feet across and about 90 feet high. Problems were encountered in the Gnome test. Cracks along a clay seam allowed much of the energy of the shot to escape into the drift tunnel, and damaged much of the experimental equipment. Gaseous materials leaked to the atmosphere, and delayed reentry for about six days (USDOE, 1996 [DOE/NV-317 (Rev. 1)]; Atomic Journey, 1999). Isotopes identified in the release included $^{131}I$, $^{133}I$, $^{135}I$, $^{137}Cs$, $^{140}Ba/^{140}La$, and noble gases. The cloud traveled in a northwesterly direction. The maximum activity measured in off-site air was 160 picocuries of gross beta activity per cubic meter of air at a nearby mine. The maximum gamma exposure rate detected off site was

1,400 mR/h at a point 3.5 miles west of the junction of Highways 31 and 128. Near Carlsbad, New Mexico, air sampling yielded concentrations of 1.7, 18, and 3.5 picocuries per cubic meter for $^{131}I$, $^{133}I$, and $^{135}I$, respectively (USDOE, 1996).

Operation Crosstie's "Gasbuggy" test occurred in Farmington, NM (about 120 mi NW of Los Alamos) on 12/10/67. It involved a LANL-supplied device yielding 29 kilotons (about 38% higher than the Trinity device), placed in a shaft. It was part of the Plowshare Program to develop peaceful uses of atomic energy. Specifically, the test in Farmington was a joint government/industry natural gas stimulation experiment. Some natural gas is trapped in rock, and cannot be extracted with normal methods. The plan was to drill a shaft and lower a nuclear device down to fracture the gas-bearing rock. This would increase the flow of gas, which would flow to the chimney area (shaft) and be piped off. Gasbuggy was a joint effort between the U.S. Atomic Energy Commission, the U.S. Department of the Interior (Bureau of Mines), and the El Paso Natural Gas Company.

Other shots for gas/oil well stimulation were:

- The "Rulison" test in Grand Valley, Colorado, that used a 40 kiloton device, and
- The "Rio Blanco" test in Rifle, Colorado that used three 33-kiloton devices.

Over the series of gas stimulation shots, the goal was to refine the devices used to obtain maximum force while minimizing the quantities of radioactive debris. The problem was that the gas that was evolved in this manner was reportedly so radioactive that it could not be distributed commercially (Kuran, 1999).

LASL provided technical direction for the Rulison project, and supplied the nuclear device. The project involved the AEC, the Department of the Interior, and the Austral Oil Company. A 43-kiloton fission-type nuclear device was detonated at a depth of 8,426 feet in an emplacement well on Colorado's western slope. The nuclear explosion produced a zone of fractured rock and a "chimney" of rock rubble around and above the detonation point. A standard gas well was drilled to the chimney, allowing recovery of natural gas. Between October 1970 and April 1971, approximately 455 million standard cubic feet of chimney gas was produced and burned ("flared") at the surface. Tests were reportedly performed to check the total radioactivity released. The main radionuclides of concern were H-3 and Kr-85. [http://www.cdphe.state.co.us/lr/en_rulis.htm].

Project Rio Blanco involved the AEC, Laurence Radiation Laboratory, CER Geonuclear Corporation, Equity Oil Company of Salt Lake City, and the State of Colorado. Three nuclear devices were placed vertically in a single well bore and detonated simultaneously in a gas-bearing formation. [http://www.cdphe.state.co.us/lr/en_riobl.htm].

In Project Shoal, a nuclear device was detonated near Fallon, Nevada, near Reno on U.S. Highway 50. Fallon is located just west of an area that has experienced frequent earthquakes. In the third nuclear experiment to be conducted outside of the Nevada Test Site, the goal was to see what effects a nuclear blast would have in an area of high seismic activity (Kuran, 1999).

Project Vela Uniform involved seven tests to determine how a country might conduct a clandestine nuclear test, and whether or not tools available were up to the distinguishing between a nuclear event and an earthquake (Kuran, 1999). Under the Limited Test Ban Treaty, shots were limited to less than 150 kilotons. Vela Uniform included the only two atomic devices that were detonated east of the Mississippi. These were conducted in Hattiesburg, Mississippi, in a huge underground salt dome. The "Salmon" shot, with a 5.3-kiloton device, was conducted to study seismic signals from an underground detonation. The "Sterling" shot, which was conducted in the Salmon cavity, was conducted to study "decoupling." In other words, would conducting a shot in an excavated cavity or the cavity from a previous shot alter the seismic signal from detonation? The shots produced a cavity

in the salt dome 2700 feet under the ground. At a point 3½ months after the detonation, the temperature in the cavity was still 400 F.

The Nevada Test Site was established 65 miles northwest of Las Vegas in 1951, because tests conducted in the Marshall Island were so expensive. In all, 928 nuclear tests were conducted at the NTS. With the increasing power of tests in the 1960s, there was concern regarding effects on the skyscrapers in Las Vegas. Officials searched for a new site for conducting high yield underground tests. Project Faultless was conducted 100 miles north of Las Vegas, near Tonopah, NV. The nearly 1 megaton shot on January 19, 1968 was a "seismic calibration" test of effects of a 1 megaton shot to see if the area could withstand a 5 megaton shot (Kuran, 1999). The ground subsided, causing faulting along natural fissures in the local geology. A 5 megaton shot, originally planned for the Tonopah site, was rescheduled for Alaska.

The Aleutian chain of islands in Alaska is in a region dotted by volcanoes and rocked by earthquakes. Amchitka, the easternmost island, was established in 1913 as a wildlife refuge.

Operation Flintlock's "Long Shot" test occurred in Amchitka on 10/29/65. It involved a device yielding about 80 kilotons, placed in a shaft. It was reportedly part of DOD's Vela Uniform project to improve the ability to detect, identify, and locate underground nuclear explosions.

Operation Mandrel's "Milrow" test occurred in Amchitka on 10/2/69. It used a device yielding about 1 megaton, placed in a shaft. It was a weapons related test, reportedly designed as a "seismic calibration" to evaluate seismic effects of underground nuclear explosions.

Operation Grommet's "Cannikin" test occurred in Amchitka on 11/6/71. It reportedly involved a device yielding "less than 5 megatons" placed in a shaft. It was a weapons related test of a warhead for Spartan antiballistic missiles. This test was done in Amchitka because it was viewed as far too large for the Nevada Test Site. It took almost two years to prepare for the Cannikin shot. A 90-inch hole was drilled down 5000 feet. Workers were lowered down this shaft, and cut out into the rock to form a 100-foot diameter sphere for placement of the device. The shot registered 6.8 on the Richter scale, and caused over 1,000 aftershocks up to magnitude 4.0 within 30 days after the test as a direct result of the detonation. The ground surface immediately above the detonation rose 25 feet, and a large portion of the coastline collapsed into the sea for a stretch of 2 miles from ground zero. The beach and ocean floor were permanently raised five feet in the near vicinity of the Cannikin shot. The Cannikin detonation was the main motivating factor in the formation of the Greenpeace organization (Kuran, 1999).

The Sedan shot in July of 1962 was part of the Plowshare program. The 104 kiloton detonation, to test methods for cratering and excavation using nuclear devices, caused dust to rise 12,000 feet into the atmosphere and created a crater 1800 feet across and 300 feet deep (Kuran, 1999).

Reference regarding nuclear testing: Kuran, 1999. "Atomic Journeys-- Welcome to Ground Zero." Goldhill Video, Visual Concepts Entertainment. Written, produced, and directed by Peter Kuran.

## 2.11 Reactors and Reactor Development Experiments

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 of 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 for neutronics experiments and isotope production. Over its history, three reactors have operated at TA-2: 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 shutdown of the OWR in December of 1992. The Water Boiler was deactivated in June of 1974, and the Clementine reactor was deactivated in December of 1950 following four years of problematic operation.

The Water Boiler Reactors

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

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 the construction of 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. This allowed for a simple design and eliminated 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 of 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 of 1944, and was used for many of the key neutron measurements needed in the early days of atomic bomb design.

In March of 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 $^{137}Cs$ (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 of 1988. The physical decommissioning process was completed in April of 1990, with the facility (TA-2-1-122) subsequently being released to the Isotope and Nuclear Chemistry division (Montoya, 1991; LA-12049).

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 of 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 9 liters per minute. Flow was maintained via an electromagnetic pump. The fuel cage was surrounded with a 6-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 6 inches thick, and finally by a 4-inch thick lead shield. Reactor (reactivity) control was effected via insertion of 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 of 1949. During this interim period, measurements were made at low power, including determination of the neutron energy spectrum, reactivity effects, cross sections, etc. Changes in the control system were also made during this time as experience in the operation of a fast reactor was gained.

In March of 1950, following nearly a full year of operation, the fast reactor was shut down to correct a malfunction in the operation of the control and shim rods. During this shutdown, a ruptured uranium rod was discovered and replaced. Operation resumed in September of 1950, and continued until late in December of that year 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 experience with the fast reactor was that mercury was unacceptable as a coolant due to 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 (Rep. No. 525). The disposal location of the mercury coolant is not known (per Rep. No. 525).

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 to meet the needs for neutron measurements for various laboratory activities. Evaluation of the options available at that time led to a conclusion that a design patterned after the Materials Test Reactor (MTR) at the Idaho National Laboratory was the most attractive. 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 8 feet in diameter and 24 feet high. The reactor would be cooled by water flowing at 3500 gpm. The proposed power level was 5 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 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. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" c. Oct. 1979, Repos. No. 615].

Construction of the new reactor began in mid 1954. Initial criticality was achieved in July of 1956, and a few months later the Omega West Reactor (as it became known) was operating at 1 to 2 megawatts. [Rep. No. 2387 states that the OWR achieved initial criticality on June 29, 1956.] In May of 1966, new operating limits were established that allowed the maximum operating power level to be increased to 6.5 MW (LA-UR-93-579). A modification to the OWR's cooling system allowed its maximum operating power level to be increased to 8 megawatts in August of 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 (LA-UR-93-579).

The OWR reportedly had an iodine-125 production loop, and at times the reactor was 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 [e.g., LA-3582-MS].

The combination of an unusual occurrence that resulted in a challenge to a safety system and the discovery of coolant leaks in underground piping prompted the shutdown of the OWR in December of 1992. 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 drew an overall conclusion that conduct of operations at the OWR facility was

inadequate (LA-UR-93-579). The three root causes specifically identified in the report were task performance errors on the part of various personnel, inadequate procedures for removal of samples from the reactor, and inadequate procedures and policies for ensuring reactor control is not compromised in the event of off-normal conditions (LA-UR-93-579).

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., 1993; LA-UR-95-4294). 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., 1993; LA-UR-95-4294).

The Omega West Reactor (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 (Rep. No. 510) describes the offgas 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 one 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 is described being hung on tree supports and ascending the canyon wall. The last half of the line had four points where 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 9) showing the offgas line relative to the Water Boiler building and the mesas north and south of Los Alamos Canyon.

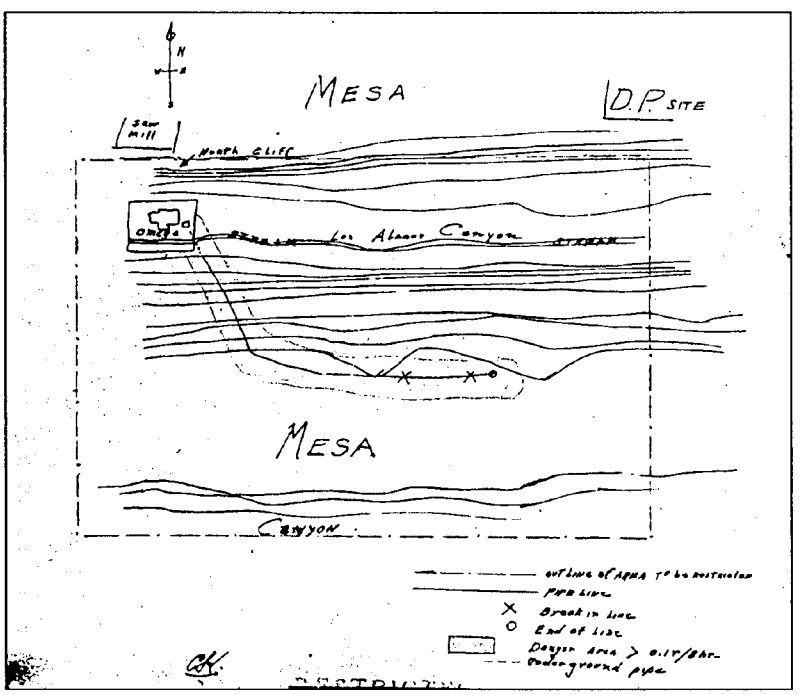



**Figure 9: Sketch of the Omega Site Off-Gas Line**

Rep. No. 510 includes 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. It is surmised that the line became brittle from the offgas and was broken due to swinging caused by recent high winds.

In later years, a 150-ft tall stack on the south mesa was used to ventilate the OWR thermal column region and experiment. The flow rate in this stack was reportedly 880 cfm. Approximately 600 Ci of $^{41}$Ar was reportedly discharged per year. [Repository No. 645]. In 1968, a charcoal filter was added in the vent line from the OWR surge talk to the 150-ft stack [Repository No. 648].

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. [Repos. No.. 510; has sketch of line to mesa top]. 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.

Rep. No. 177 includes a memo from D. D. Meyer to D. Ritter (ENG-4) dated June 11, 1957 that requests removal of the barbed wire exclusion fence that kept people 50 feet or so away from the Omega stack. 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. It is requested that the old stack be taken down and sent to the "contaminated waste pit."

A second memo included in Rep. No. 177 (from D. D Meyer to Carl Buckland), also dated June 11, 1957; states that P-2 plans to connect the offgas system for the OWR to the existing system for the Water Boiler (SUPO). Per Rep. No. 2414, this action was completed between September 20, 1957 and October 20, 1957.

A charcoal filter was installed in the vent line for the OWR surge tank air space in 1968 (Rep. No. 648). 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.

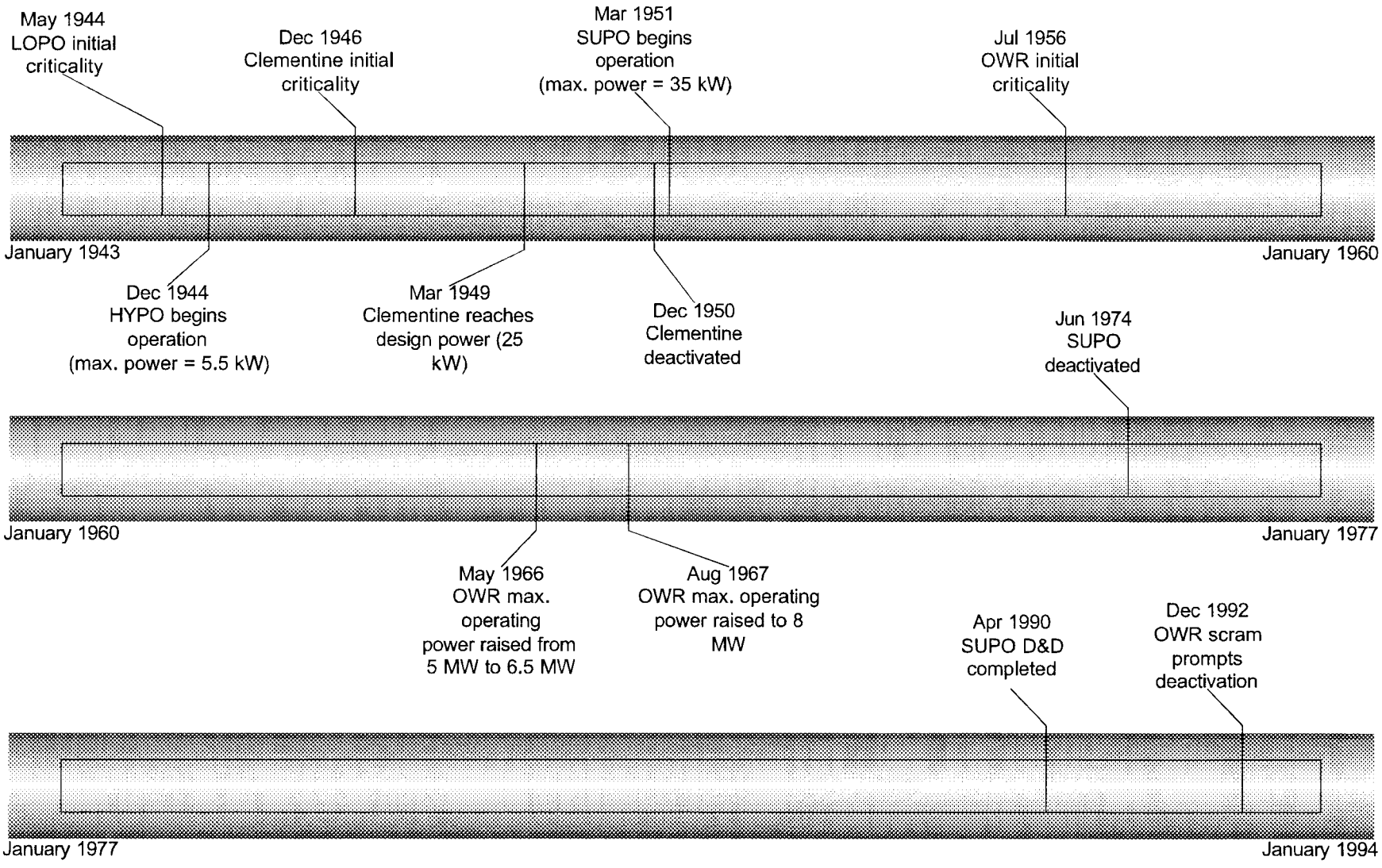
Hankins (1963) describes the Omega stack as being 150 feet long and having an inside diameter of 8 inches. The 2 inch (inside) diameter vent pipe from the reactor to the stack was 1100 feet long. The vent pipe included a settling tank and two water traps to collect water that condensed out of the effluent. The delay time of gas in the vent pipe was originally 2.3 days, 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 cc/min, resulting in a dilution factor of about 100,000 in the stack. The stack flow rate was measured to be 845 cfm at a velocity of 2400 fpm.

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 10.

**Figure 10: 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 (LA-2292). Protection of 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 (LA-2292).

The first critical experiments with LAPRE I began on February 15, 1956 (LA-2292). 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. It was found that some of the gold plating on the heat exchanger tubes had been damaged during assembly of the reactor, which allowed 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 (LA-2292). Chemical attack was also noted at imperfections in the plating of the vessel and the boron poison can (LA-2292).

Since the failure of LAPRE I was not due to the reactor itself, components were repaired or replaced as thought necessary and a second attempt at operating the reactor was made (LA-2292). This second experiment was conducted on October 15, 1956. The reactor reached a power level of 160 kW and had been held there for approximately 2 hours when radioactivity was detected in the feedwater and steam systems, prompting a shutdown. Activity in the steam line rose rapidly, resulting in dose rates of 300 mR/hr in the control room (LA-2292). This was thought to be due to gaseous activity released from the end of the steam line and drawn into the building ventilation system (LA-2292).

Post-mortem inspection of the reactor determined the failure was again due to the heat exchanger tubes having been eaten away by the fuel solution. Since construction of LAPRE II was already underway at this time, further work with LAPRE I was abandoned (LA-2292).

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 expenses of less uranium solubility and thus the requirement for a larger vessel to achieve a critical mass. LAPRE II was also to make use of bonded components, in hopes of solving the failures associated with the protective gold plating.

Construction of LAPRE II was begun in February of 1956 (Clark, 1960; LA-2465). The reactor was located in an underground enclosure tank on the south side of the main laboratory building at TA-35. This arrangement provided a prudent means by which to provide 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 was begun in February of 1959 and continued into May of 1959 (Clark, 1960; LA-2465). 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 the leakage of volatile fission products into the steam system. At full power, dose rates of several thousand R/hr were present adjacent to the feedwater heater (Clark, 1960; LA-2465). Though it could never be determined for certain, it was suspected that the leakage occurred via 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; LA-2465). 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 Los Alamos Molten Plutonium Reactor Experiment (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 the LAMPRE I therefore underwent substantial changes, going 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 gain 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 was corrosion of the tantalum fuel thimbles by 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 La-140 separation. It used molten Pu 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 (LA-UR-79-3091).

LAMPRE experienced three separate fuel failures during operation; official reports say that these fuel failures did not cause any *operational* problems. [LADC-5936, CONF-258-1 by Robert A. Clark and Review of LAMPP by Argonne NL (PRO-P-1; 4/20/66)]

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; LA-10062-H). The plan was to carry large payloads into deep space, by essentially passing hydrogen through a very high temperature nuclear reactor,

where it would expand and be blasted out of the reactor at high velocity. Conducted with NASA, this program was called Project Rover. Los Alamos was given the roles of establishing the basic reactor design and leading the fuel development effort (Koenig, 1986; LA-10062-H). A series of test reactors were designed and built at Los Alamos 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 LASL. The Rover program was cancelled in January of 1973.

The Rover reactors were developed by the Los Alamos Critical Experiments Group using the facilities of 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 checked out prior to being sent to NTS for testing. Adjustments were made if any deviations from specifications were noted during checkout (Paternoster and Kirk, 1991; LA-UR-91-2434). Each Rover program reactor developed at Los Alamos is listed in Table 3 below, along with the date the reactor was tested at NTS (Paxton, 1983; LA-9685-H).

**Table 3: 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 says that the DP East facility processes 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 are monitored but concentrations were reportedly below detectable levels. [Repos. No.. 113].

UHTREX

The Ultra-High Temperature Reactor Experiment (UHTREX) involved the construction and operation of a test reactor to advance the technology of high-temperature, graphite-moderated, gas-cooled reactors. The reactor was constructed in the late 1960's at Technical Area 52, and operated for approximately one year before being shut down in February of 1970 (Salazar and Elder, 1993; LA-12356). 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 (K-division, 1967; LA-3556 Revised). Under maximum conditions, the gas temperature at the core inlet was 1600 F, and the exit temperature was 2400 F (Salazar and Elder, 1993; LA-12356). The secondary loop coolant entered the heat exchanger at 200 F and exited at 1000 F (Salazar and Elder, 1993; LA-12356). 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 3 layers of pyrolytic carbon and bound in a graphite matrix (K-division, 1967; LA-3556 Revised). Fuel for the UHTREX was fabricated at the CMR Building (K-division, 1967; LA-3556 Revised). 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 3 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; LA-12356). 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) (K-division, 1967; LA-3556 Revised). Delay times for the carbon bed were 1.2 hours for krypton and 20 hours for xenon (K-division, 1967; LA-3556 Revised). Under maximum conditions, 13 kW of decay heat were produced in the charcoal bed (K-division, 1967; LA-3556 Revised). 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 (K-division, 1967; LA-3556 Revised). This tritium was eventually discharged up the 100 foot high main stack during regeneration of the sieve beds (K-division, 1967; LA-3556 Revised). This process also resulted in the discharge of entrained fission gases (K-division, 1967; LA-3556 Revised).

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 (K-division, 1967; LA-3556 Revised). Stack releases were monitored via a Tracerlab model MAP-1B/MGP-1A combination gas and particulate monitor (K-division, 1967; LA-3556 Revised). 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 (K-division, 1967; LA-3556 Revised). The UHTREX facility was designed so that air flow was 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 could be evaluated utilizing the hot cell facilities there (K-division, 1967; LA-3556 Revised). 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 1980's. All radioactively-contaminated solid waste was buried at the laboratory's central waste disposal facility (TA-54) (Salazar and Elder, 1993; LA-12356).

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## 2.12 Accelerators at Los Alamos

During World War II, accelerators were used to determine the critical masses 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).

The machines supplied neutrons for studying the neutron interactions involved in an explosive fission chain reaction. This was important because these interactions had not been studied at all of the neutron energies relevant to a nuclear explosion., from which fast neutrons are emitted with no slowing down or "moderation" as had been the case in the early graphite reactors. 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, Los Alamos Science No. 21).

During the postwar years, the 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 those provided by 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, Los Alamos Science No. 21).

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 xray bursts are sent through model weapons at a remote blasting site to provide three-dimensional images of imploding spheres. (Reichelt, 1993, Los Alamos Science No. 21).

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, hit a target (usually lithium), producing neutrons. Some X rays were also produced. There were also hazards from neutrons and X rays.

- TA-3 Building 16 housed a Van de Graaf accelerator (aka SM-16). On 24 May 1977, there was a release of up to 800 Ci of tritium from the Van De Graaf accelerator. [Repository Nos. 593, 829]

The largest accelerator facility at Los Alamos is the one that is housed at TA-53. 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 million electron volt (MeV), 1-milliampere intensity proton linear accelerator. Construction was started on LAMPF in 1968. On June 12, 1972, LAMPF first obtained a full energy beam. Originally constructed to study sub-atomic particles, today LAMPF 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 Proton Storage Ring 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.

LAMPF releases to air consist primarily of short-lived radioactive materials that have been activated from air. Cooling water used for accelerator components provides a source for liquid radioactive releases. Non-radioactive releases at accelerators include solvents, which are used in large volumes for cleaning vacuum components. The high electrical power used by the accelerator-required transformers and cooling water.

Site documents refer to the mix of short-lived materials as Mixed Activation Products (MAP). These 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.

Operations at LAMPF form activated air products that are exhausted to the air through a tall stack. For some periods of time, these emissions reportedly accounted for the largest boundary dose and individual dose from all of LASL operations. The doses reported are among the highest of all DOE operations nation-wide. The amounts released (and thus dose) will increase proportionally as the power levels and beam time increase. LAMPF was at 40-50% of design beam time in 1978. In 1978, 117,000 Ci of air activation products were released to the environment from LAMPF. Principal radionuclides were $^{11}C$ (20 min), N-13N (10 min), $^{15}O$ (2 min). A trace amount of $^{41}Ar$ (1.8 h) was also released. Measured doses at the site boundary were 14 mrem for 1978 based on extrapolation from 6 months of TLD data that compared well with 3 months of high-pressure ion chamber measurements. This measured dose is 13% of natural background for Los Alamos. Based on occupancy time of 67 h/wk, and accounting for shielding by the building, the calculated dose to a worker at Philomena's Restaurant is 3.8 mrem for 1978. Calculated boundary and individual doses are much higher (126, 67, and 22 mrem at the boundary for 1978, 1977, and 1976, respectively. The calculations are based on conservative plume diffusion models that are of limited value in the complex terrain of Los Alamos. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" c. Oct. 1979]

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 via concrete walled cooling water ponds that have bentonite clay on the bottom. The cooling water is held up and no short-lived nuclides are observed in water. The cooling water and ponds are a source for subsequent releases offsite to surface water.

The prioritization method described later in this report divides each stacks yearly release by the derived air concentration limit (DAC) for non-occupational exposures. The result represents the volume of air required to dilute the releases to the maximum permitted, and permits comparisons for varying amounts of radioactive material from year to year based on the total quantities of air required

to dilute the effluent. There are no published DACs for short-lived MAP. ICRP 60 methodology was used to estimate the DAC for the nuclides that comprise the releases from LAMPF.

The first approach for prioritization shows that LAMPF dominated site releases to air since the late 1970s. Repository No. 1071 mentions that short-lived activation gases were not reported at LAMPF for the 1974 to 1978 time frame. The LANL summary documentation used for the current version of the prioritization shows negligible releases for LAMPF for that time period. When the actual releases from LAMPF are estimated for that period, it is possible that LAMPF will dominate prioritization schema used by the LAHDRA project for site releases before the late 1970s.

Reconstruction of releases from LAMPF for the years prior to 1978 will require process information. Because the dominant releases to air are short lived, there is no opportunity for an inventory of radioactive materials to build up. The second iteration of the prioritization may include estimation of the pre-1978 source term using simple scaling from process variables such as beam energy and intensity delivered to targets, along with the beam line layout. This information will need to be retrieved as part of the ongoing document retrieval effort. As a large portion of paper records at the Central Records Center has been completed with no operational information such as beam current and energy, this data will likely be found in records located at TA-53.

One of the documents abstracted (Repository Number 441) refers to a letter to the AEC concerning LAMPF airborne emission in 1970, so 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 $^{7}Be$. (It is not known whether the change in stacks was driven by the need to limit the releases).

Cooling water was released to floor drains that fed two 2,500-gallon carbon steel tanks. These tanks were discharged to the cooling water ponds (Repository No. 503).

The magnitude of releases resulted in continuing studies to estimate the offsite impact. One such study was LA-11150-MS, which documented the releases and modeling of the releases for 1985 (Repository No. 2145).

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 is assessed with on-line monitoring, and through TLDs located at various locations

Repository No. 1556 (not yet released by LANL) discusses the fugitive releases from LAMPF for 1990, which were 0.21 curies, a small fraction of the 120,000 curies of short-lived gases that were reported. The fugitive emissions were comprised of longer lived nuclides, and a comparison of curies alone might be misleading, but the magnitude of fugitive emissions is clearly less significant than that of the primary release points.

Accelerator complexes within DOE have been found to release large quantities of solvents. Little operational data concerning the quantities and releases have been found for the 1970s and 1980s during the systematic search of the CRC records holdings.

The LANL assessment of the impact of radioactive releases from TA-53 has changed in other ways over the years. Prior to 1991, the site assessed the releases taking credit for estimated occupancy and

the inherent shielding provided by residences. In 1992, LANL was told by the USEPA that no credit should be taken for shielding and residency time factors (Repository No. 713). This resulted in a changed methodology for reporting impacts from the releases. Care should be taken when comparing LANL reported impacts from different operating periods at TA-53.

## 2.13 Criticality Testing

History of Technical Area 18 (Pajarito Canyon Laboratory)

The site was first developed in mid-1943 and used by the Radioactivity Group (Hawkins, LAMS-2532). The site was chosen because it provided a remote location where experiments could be performed away from the radiation background associated with the main technical area (TA-1). In 1944, G-Division began using the area as a firing site for explosives (implosion) diagnostics (Rep. No. 517). Three firing sites were established, called small, medium and large (Rep. No. 531). The small site, located in the west wing of the canyon, was intended for small explosive charges of a few pounds each (Rep. No. 517). The medium site, located in the south wing, was for charges up to several hundred pounds; and the large site (east wing) was for charges of up to 2 tons. However, the large firing site was never used for this purpose (Rep. No. 531). The medium site was instead modified to make it suitable for up to 2-ton charges in 1945 (Rep. No. 517). It appears the large site was used for drop testing of both inert and high explosive units (Rep. No. 517). The small and medium firing sites included two large, concrete structures called battleships used to protect equipment during tests of the magnetic method for implosion diagnostics (Rep. No. 517).

Nuclear criticality experiments were first moved from Omega Site (TA-2) to Pajarito Site in April of 1946 following the fatal radiation injury to Harry Daghlian (Paxton, 1981; LA-7121-H). Initial work was done in a 26- by 40-foot addition to the central laboratory building previously used by M-division (Rep. No. 517). A second fatal radiation injury to Louis Slotin about a year after the death of Daghlian prompted a ban on "hand-operated" critical experiments, and consequently, a need for a facility for remotely operated critical assemblies (Paxton, 1981; LA-7121-H). The Integral Assembly Building (more commonly known as Kiva 1) was therefore commissioned, with operations there beginning in April of 1947 (Rep. No. 517) (Paxton, 1981; LA-7121-H).

The initial work performed at Kiva 1 was to establish handling and storage guidelines for weapons and weapons components (Paxton, 1981; LA-7121-H). Experiments were performed using a combination of assembly machines and critical assemblies. The first assembly machine was known as the bomb mockup, as it was sized similarly to the Fat Man weapon used at Nagasaki. This machine was used for sub-critical experiments only (Paxton, 1983; LA-9685-H). In October of 1948, criticality of the Topsy machine was reported by the W-2 group (Paxton, 1981; LA-7121-H). Topsy, which consisted of enriched uranium in a natural uranium reflector, was the first in a series of devices used to provide fast neutron data for benchmarking computer codes (Paxton, 1981; LA-7121-H). Topsy was initially used for sub-critical experiments, but was dedicated to critical work in the fall of 1948 (Paxton, 1983; LA-9685-H). Topsy was replaced with a machine called Elsie. Elsie was followed by Little Eva, which was similar to Topsy in that it consisted of enriched uranium in a natural uranium reflector. (Little Eva was moved to the Nevada Test Site in 1958 to calibrate activation foils used for diagnostic measurements on the various Rover program reactors (Paxton, 1981; LA-7121-H).) The Comet machine also followed the Elsie machine, being used for both critical and sub-critical work. Comet proved to be such a popular device, a twin called Planet was constructed (Paxton, 1983; LA-9685-H). A betatron (electron accelerator) was used at Pajarito Site from May of 1951 until the fall of 1954 (Paxton, 1981; LA-7121-H).

In August of 1951, an unclad sphere of enriched uranium metal called Lady Godiva began operation. This assembly was used for delayed-critical work through 1952. A plutonium core was added to the Topsy assembly about a year after Lady Godiva came into use (Paxton, 1981; LA-7121-H). Use of

the Lady Godiva assembly prompted the construction of a second experiments facility, called Kiva 2, which was completed in February of 1953. At this time, the entire critical experiments group relocated to TA-18. The group's offices had previously been housed at TA-1 in the Gamma Building (Paxton, 1981; LA-7121-H).

The Lady Godiva assembly was moved to Kiva 2 upon its completion and began operating there. However, it was portable, and thus was sometimes used at other areas of the LANL site. In mid-1953, Lady Godiva began being used for super-prompt critical bursts to supply pulses for a variety of experiments, including evaluation of weapon test instrumentation, materials research, and biological research. The assembly was used for approximately 1000 prompt-critical bursts until one in 1957 took it beyond what it could physically withstand. The assembly suffered severe warping and oxidation, rendering it unusable. The assembly had actually been similarly damaged previously in February of 1954, but the warping that occurred was not so severe that it could not be repaired. Lady Godiva was replaced with the Godiva II assembly, which was specifically designed for prompt-critical bursts.

In late 1954, an assembly called Jezebel came into operation. Jezebel was a unreflected sphere of delta-phase plutonium containing 4.5% $^{240}$Pu (Paxton, 1983; LA-9685-H). In later years, it also operated using a bare sphere of $^{233}$U (98.1%) and an additional plutonium sphere containing 20.1% $^{240}$Pu (Paxton, 1983; LA-9685-H). Use of the $^{233}$U core was discontinued following its evaluation, as the intense gamma-ray emission due to the $^{232}$U impurity made for handling and measurement problems.

In 1958, the Topsy machine was replaced with a machine called Flattop, which was named for the Dick Tracy character. It first operated with an enriched uranium core, with cores of $^{233}$U and plutonium being added subsequently. Unlike the $^{233}$U core for the Jezebel assembly, the one for Flattop was retained since it was small enough that the gamma emission was tolerable (Paxton, 1981; LA-7121-H).

Other critical assemblies employed at Pajarito Laboratory include:

- Jemima: intermediate-enriched uranium used in the Comet machine in 1952.
- Molly G: a prompt-critical burst assembly modeled after Godiva 2. Following calibration at Kiva 2, Molly G was shipped to the White Sands Missile Range in July of 1964 where it became known there as the "Fast Burst Reactor."
- Hydro: a 10 kW neutron source consisting of a cylindrical core of 93%-enriched uranium. Hydro was operated outside of Kiva 2 to eliminate room return.
- PARKA: a Phoebus 1 reactor left over from the Rover program and set up as a critical assembly.
- Big Ten: a cylindrical system consisting of 10-enriched uranium used to establish cross-sections for fast power reactors.
- Kinglet: experiments to establish design parameters for the KING (kinetic intense neutron generator) reactor project that was never funded.
- Mars: a large, general-purpose vertical assembly machine.
- Godiva IV: a portable fast burst assembly (successor to Godiva II).
- SHEBA: the solution high-energy burst assembly, used to evaluate criticality accident detection systems.
- SKUA: the supercritical uranium assembly (another fast-burst assembly)
- Thor: a spherical plutonium benchmark assembly

In the spring of 1955, the critical experiments group became involved in the Rover nuclear propulsion program. They were involved in the design, assembly and zero-power testing of a series of graphite-

moderated propulsion reactors (rocket engines). The Rover program dominated activities at Pajarito Site until 1972. The Rover effort required a third experimental facility (Kiva 3) to be built at TA-18. Kiva 3 was completed in 1960.

The bulk of the Rover effort was dedicated toward developing a series of graphite-moderated test reactors called Kiwis (as they were flightless birds). However, an alternative to graphite-moderated reactors was pursued for a short time earlier in the program. This project, called Dumbo, was abandoned in the fall of 1959. The Kiwi reactors evolved from the Kiwi-A series, the first of which being tested at the Nevada Test Site in July of 1959; to a water-moderated system called the Nuclear Fuel Furnace, tested at Nevada in July of 1972. The Rover reactors are discussed in more detail in the section on nuclear reactor development. Rover research at Pajarito Site also included use of a horizontal assembly of square aluminum tubes called Honeycomb. Honeycomb was used for parametric studies needed to support development of the Rover reactors.

Following the cancellation of the Rover program, the critical experiments group conducted research for NASA into the development of plasma-core power reactors. Mock-ups for this research initially used components left over from the Rover program before progressing to systems using gaseous $UF_6$. A complete $UF_6$ system was never achieved, however. The NASA work also involved the study of using lasers to transmit power, resulting in the first demonstration of a laser pumped by uranium fission products (Paxton, 1981; LA-7121-H).

Impacts of Activities Associated with the Critical Experiments Group

Operations of the various assemblies at the Pajarito Site result in elevated radiation levels along Pajarito Road while the devices are in use. From Rep. No. 615, "extensive gamma and neutron measurements were made during operations of the various machines at Pajarito Site in 1975. Extrapolations from these measurements indicated the annual dose rate (from gamma plus neutron radiation) at the most exposed location on Pajarito Road was 1120 mrem/yr in 1975" using an assumption of continuous occupancy. The same document asserts a member of the public would receive an annual dose of 1 mrem from Pajarito Site operations in 1975 assuming they drove by the site 15 round trips a week at a speed of 40 mph and that the dose rate was "rather uniform with time over the work day."

Other impacts of operations at the Pajarito Site include instances of releases of airborne radioactive material from the Kivas, instances of removable radioactive contamination being tracked out of the Kivas and spread to offsite locations, and releases associated with the processing of irradiated fuel elements at other areas of the LANL site. Examples of items identified in the LAHDRA project database pertaining to TA-18 activities include:

- On January 8, 1953, it was discovered that a polonium-beryllium neutron source had ruptured at Pajarito Site and that "possibly as much as 2 curies" of polonium had been lost. "Significant amounts were found in a number of homes", though most of the contamination was "in and around" the facility. Urinalyses performed on individuals residing in the affected homes showed no polonium intakes "in amounts greater than permissible limits." No quantitative urinalysis results are provided, however. The greatest contamination was limited to three homes, though "lesser amounts were found in a large number of others." Items in the homes found to be contaminated included shoes, clothing, floor coverings, vacuum cleaners, children's toys, baby diapers, "etc., indefinitely." (Rep. No. 124).
- An excursion of the Godiva assembly on February 12, 1957. "Components were thrown about the kiva" and dose rates in the kiva following the event were reported to be "several R/hr." Cleanup commenced following 3 days of decay and took 5 days to complete. "Gross quantities of [U-] 235 reading in excess of 20,000 c/m were measured." (Rep. No. 18).

- Neutron dose rates at Kappa Site (TA-36) resulting from operations at TA-18 were identified as a concern by the H-1 group in 1957. The highest neutron flux was measured in December of that year when the Hydro assembly was operating. It is reported than a 18.5 minute tolerance was measured at the Kappa Site guard station, with a caveat that the film badges being used have a "blind spot" for neutron energies making up a "good share" of the flux at that location. (Rep. No. 18).
- Air samples acquired by H-1 in 1957 in the vicinity of the Honeycomb assembly were reported as being half of the applicable tolerance level for that era, and samples in the vicinity of the Lady Godiva assembly were asserted to be "excessively high." This is cited as justification for plating the "new" Godiva (presumably Godiva II). (Rep. No. 18).
- Three air samples obtained in 1960 during loading of the Super Comet machine with U-235 averaged 160 dpm/m$^3$, with the maximum reading being 295 dpm/m$^3$. These measurements were significantly higher than the applicable tolerance level for that era of 66 dpm/m$^3$. (Rep. No. 141).
- "Above normal" air counts were detected during disassembly of the Molly G assembly in preparation for shipping it to White Sands on July 20, 1964. (Rep. No. 72).
- A H-1 progress report for November of 1964 gives I-131 concentrations in room air, in the exhaust system, and at a position 500 feet northeast of the TA-46 facility where fuel elements from one of the Rover reactors (Kiwi B4-D) are being processed. The highest concentration found in the exhaust system was $4.9\times10^{-2}$ $\mu$Ci/m$^3$. The highest concentration in an "intermittently occupied" room was $3\times10^{-3}$ $\mu$Ci/m$^3$, and the highest concentration measured northeast of the building was $1.3\times10^{-6}$ $\mu$Ci/m$^3$. (Rep. No. 72).
- On August 22, 1979, an estimated 220 ± 20 grams of gaseous $UF_6$ (93%-enriched) was released into Kiva 1. The release occurred from an "experimental apparatus" during "routine operations." "Several people" received "small exposures to active material" as a result of the incident and the subsequent cleanup. The document asserts that 90% of the material was trapped in the facility's HEPA filter, with the majority of the remainder ending up on the floor or in the oven that was being used. The release to the environment was estimated to be 0.0035 grams, or 0.32 $\mu$Ci. (Rep. No. 137).

Accelerator operations, low power critical assemblies, and burst reactors at Pajarito Site (TA-18) cause radiation levels for brief periods along Pajarito Road that can be perceived as large on this major thoroughfare between Los Alamos and White Rock. Up to 1120 mrem/y from gamma plus neutrons in 1975, assuming continuous occupancy along TA-18 boundary. However, actual occupancy time is very small for members of public. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" c. Oct. 1979]

The Pajarito Lab facility is now in "stand down." Workers discovered bones of a Native-American burial area near Kiva 3; this is considered a very sacred area.

## 2.14 Fusion Research

Some of the first steps towards producing controlled nuclear fusion were taken at Los Alamos Scientific Laboratory. In 1952, six men and $50,000 were assigned to a laboratory trial of the theories concerning the isotopes of hydrogen. [The First 20 Years at Los Alamos, The LASL News] Experiments were begun in a corner of the old U Building in TA-1 with the heavy core of an abandoned betatron machine as the heart of what was hopefully dubbed the "Perhapsatron," because "perhaps it would work and perhaps it would not."

"Sherwood" was the name given to the project by the AEC. The project started at LASL in 1951, and expanded beyond Los Alamos to become a nationwide effort. Huge electrical condensers were

assembled in the Project Sherwood Building. In 1968, there were 60 workers in Sherwood Group at LASL. The unfulfilled promise of fusion led to closing of project by the mid-1970s.

The Perhapsatron was first operated in the fall of 1952, shortly after the "Mike" test in the Pacific proved that thermonuclear fusion was indeed possible. The Perhapsatron did not work, but it encouraged further study in a new field of science-- plasma physics.

The Perhapsatron used a toroidal Z-pinch, in which an induced toroidal current in the plasma produced a self-magnetic field that pinched the plasma column. After the Perhapsatron came a servies of devices that used the "pinch effect" to seek the high temperatures needed for fusion. After the doughnut-shaped torus of the Perhapsatron came "linear pinch" machines such as the "Columbus" devices. Next, "Scylla" devices applied sudden compression on all sides by applying a strong magnetic field. Scyllac was located at TA-3 in Building SM-287. Scyllac was an 8-m diameter controlled thermonuclear reaction device. Los Alamos achieved the first controlled thermonuclear plasma in 1957 in the Scyllac theta pinch device. Used a rapidly rising axial magnetic field to heat plasma through a combination of shock and compression heating.

"Laser laboratories" for fusion research began construction at TA-35 in 1974 [Repository No. 120]. TA-35's HELIOS and ANTARES are LANL laser facilities for ICF research (laser fusion). HELIOS is a 10 kilojoule $CO_2$ laser fusion system (10 micron wavelength) and ANTARES is a 40 kJ 24 beam $CO_2$ laser fusion driver. ANTARES was completed in 12/83. [Nucl. Weapons Databook, Vol. III]

In 1958, physicist John Marshall developed a hydro-magnetic gun capable of "shooting" a plasma at terrific velocities. This was a new method for use in testing theories of plasma heating and confinement. [LASL News: The First 20 Years at Los Alamos]. The "Pu Gun" reported to be at TA-35 per Repos. No. 225 (c. 1981) may have been this device.

## 2.15 Plasma Thermocouple

The plasma thermocouple program involved research into methods for converting nuclear fission energy directly into electrical power. This idea was born around 1942, and "direct conversion" was first achieved by LASL physicists in 1958 [LASL News, The First 20 Years at Los Alamos]. N Division was created at LASL in 1955 to study potential methods of nuclear propulsion in space. The group centered their efforts on Project Rover, in which LASL's Kiwi reactors were developed, and ion or plasma propulsion for the far reaches of space. Direct conversion was the first choice as power source for plasma propulsion.

As of 1963, there were more than 50 people working on the plasma thermocouple problem. The method worked on the principle of conventional two-metal thermocouples that produce small amounts of electricity when one junction is hotter than the other. Scientists substituted an easily ionized gas for one of the metals. When they electrically heated the metal emitter of the plasma thermocouple, cooled the container around it, and introduced plasma or ionized gas such as cesium, a stream of electrons flowed to they outside wall where they were collected [LASL News, The First 20 Years at Los Alamos]. Later models used the energy of nuclear fission to provide the heat. The goal of the program was to provide a power supply package for space application with no moving parts or heavy turbines or generators.

## 2.16 The LANL Health Division and Biological Research

Although the Health Division at LANL was responsible for monitoring worker health, instances of overexposure to chemicals, explosives and radionuclides in the workplace could indicate a routine or accidental release of materials to the environment as a result or failed containment or increased ventilation as a solution for reducing worker exposure.

The project team has located and reviewed over 150 Health Group (later Division) Progress Reports in the repositories at Los Alamos National Laboratory. The reports were produced on a monthly basis, although several annual and quarterly reports from the Health Division have also been identified. The oldest report is a Health Report dated November 1943, and the most recent report located to date was published in October 1960. No reports for the years 1945 and 1946 have been located to date. However, a document titled "History of the Health Group", March 1943-November 1945 was identified that included operational information for that period.

History of H-Division

According to the report titled "History of the Health Group" (Hemplemann 1945; Rep. No. 978), a directive from Mr. Oppenheimer, dated November 13, 1943, stated that the medical supervision of technical personnel was to be directed primarily at protection of persons from the hazards of the project. The primary function of the Health Group (A-6) was to establish safe tolerance levels, develop monitoring methods, and to ensure that tolerance levels weren't exceeded. Routine monitoring procedures were turned over to the group concerned whenever possible (e.g., CM-1).

The original policy of the Health Group was to depend entirely on information gained from health research groups elsewhere. Because that policy did not always provide the proper data in time to establish safe operating procedures, research sections were set up within the Health Group (e.g., instrumentation and biological methods of testing for overexposure) (Hemplemann 1945; Rep. No. 978). For example, approximately half of the 25 to 30 page monthly reports describe various areas of research and papers published on the health effects of radiation by H-4, Radiobiology, and instrument development and performance work conducted by the electronic and biophysics sections of Radiologic Safety, H-1. Accidents are reported in the Occupational Safety group (H-3) section of the division reports.

On June 1, 1947 the Health Group became the Health Division (Hemplemann 1947; Rep. No. 2202). L. H. Hemplemann, MD, was the Division Leader from 1943 until the end of 1948, when T. L. Shipman, MD, took over (Rep. No. 2270). In 1943 the Health Group consisted of 10 people (Hemplemann 1945; Rep. No. 978). In 1949, there were 97 members of H-Division (Rep. No. 2266), and in 1951, there were 158 (Rep. No. 2287).

Documentation of H-Division Activities

The reports of the Health Group are called Health Reports, and the Division reports are called H-Division Progress Reports. The Health Reports are organized in three sections: radiation problems, chemical hazards, and general safety. The monthly progress reports are generally presented in four to seven parts, describing the activities of the four to six numbered groups and the Administration Group that operate within the Health Division:

- H-1 Administrative and Medical Records later became Radiologic Safety; 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 (same functions as the old Health Group), industrial hygiene, and occupational biochemistry sections; later when Radiologic Safety became a separate group called H-1, Occupational Medical was created to maintain responsibility for general clinical functions such as physicals and first aid.

- H-3 Training of Military personnel (animal research) 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 this group in June 1949.

- H-6 Monitoring (CMR-12) was merged into H-1 and then became Radiologic Physics, including the old Biophysics group (now called Special Problems) and the Meteorology section.

Constructed during 1952-54, the Health Research Laboratory at TA-43 is adjacent to the Los Alamos Medical Center in the townsite. Research performed at this site has 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.

Health Division Perceptions of Hazards at Los Alamos National Laboratory

In 1943, the hazards of the project were reported to be limited to external radiation from the cyclotron, the Van de Graf, the D-D source and the radium sources. There were also hazards due to uranium and the usual chemical laboratory hazards, but these were not serious, according to Hemplemann (1945). Only one accident occurred during the first year that involved overexposure to radiation from the cyclotron. The main concern of the Health Group at this time was the interpretation of blood counts on exposed personnel. Normal variation in blood counts was not well known at the time (Hemplemann 1945; Rep. No. 978).

In February 1944, plutonium arrived at LANL in significant quantities. The members of Chemistry and Metallurgy (CM) Division and the Health Group became concerned about the dangers of working with this material. Control of alpha radioactive materials worked out well for the first year. After an accident in August 1944 where a milligram of plutonium blew up in someone's face, a research program to develop tests for detecting overexposure of personnel with plutonium began. A urine test was developed in January 1945; it required a new (free of alpha contamination) laboratory (ML Building). Following the first human tracer experiment in April 1945, results of the urine tests were evaluated with some certainty. Until the urine test was perfected, nose counts were the only index of personnel exposure. Due to the difficult and time consuming nature of the urine test, the most heavily exposed persons as indicated by nose counts had the most urine examinations. Available alpha monitoring equipment lacked either sensitivity or portability, so swipe samples were used to detect contamination of hands and nostrils. 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 (Hemplemann 1945; Rep. No. 978).

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, one group, HI (CM-12), was given full responsibility for the entire alpha contamination problem in the CM Division. At this time it was necessary to redesign the existing facilities in D Building in order to safely handle the large amounts of plutonium in that laboratory. The facilities were adequate with one exception. In July 1945, CM-5 handled amounts of plutonium that exceeded the capacity of its safety equipment and four persons exceeded the safe amount of one microgram of plutonium in their bodies according to urine tests.

According to Hemplemann (1945), polonium was never the hazard that plutonium was. Less radioactivity, an easy urine test method, and relatively simple technical operations resulted in polonium never being a serious hazard. Only two persons ever exceeded the tolerance limit for polonium (1500 cpm in a 24-hr urine sample).

The initial external radiation hazard at LANL did not change until September 1944 when the water boiler at Omega Site went into operation. Later when the power boiler went into operation (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 the active material. There were two serious accidents that resulted from critical assembly work, also at Omega, one that overexposed four individuals to gamma and neutron radiation, and one fatality (Hemplemann 1945; Rep. No. 978).

During the radioactive barium and lanthanum (RaLa) implosion tests that started in September 1944, members of the chemistry group CM-4 received periodic overexposures to beta radiation (Rep. Nos. 978, 2207, 2261, 2268).

According to Hemplemann (1945), the toxicity and accepted methods for prevention of toxicity from exposure to high explosives were obvious. In certain cases, safe operational procedures were delayed by inadequacies in construction of exhaust systems, washrooms, etc., but no serious trouble was encountered between March 1943 and October 1945.

Although monthly H-Division reports from 1947 forward repeatedly mention the hazards of beryllium (Rep. Nos. 2202, 2262, 2270) there is no mention of beryllium in Hemplemann (1945).

Table 4 presents a summary of materials of concern in terms of potential health hazard, based on review of H-Division reports.

**Table 4: Materials of Concern from H-Division Reports**

| Material of Concern (Location of Concern) | Examples of H-Division Reports (Project Repository No.) |
|---|---|
| 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 |

Human Tissue Analysis Program

The human tissue analysis program was a 35-year-long effort by Los Alamos National Laboratory to study the levels of plutonium in workers and in the general population of the United States. The general population was exposed to plutonium from atmospheric testing of nuclear weapons. Populations located near plutonium facilities, such as the D Building and DP Site in Los Alamos, were also exposed to plutonium released during operations.

Compilations of the data have been published periodically, and the Los Alamos Science Magazine summarized the program in the November 23, 1995 issue that was devoted to a discussion of the Human Radiation Experiments. That issue is available on the LANL Library's web page.

The data have been analyzed by Los Alamos in analyses that are said to demonstrate that the differences between states in the median values of plutonium concentration in tissue were small. 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, as compared to other states. Data from the human tissue analysis program are discussed in Appendix A.

References related to H-Division:

Health Group Reports (1943-44) and H-Division Progress Reports (1947-60). Project Database Repository Numbers 2202-2434.

Hemplemann, L. H. 1945. "History of the Health Group, March 1943-November 1945". Project Database Repository Number 978.

## 2.17 Waste Treatment and Disposal

Liquid Waste Disposal

TA-45, (not currently active): Untreated liquid wastes from TA-1 were discharged to Acid Canyon starting in late 1943 or early 1944 and continuing through April 1951. By June 1951 the TA-45 Radioactive Liquid Waste Treatment Plant (a.k.a. WD Site) began treating the wastes by a flocculation-sedimentation-filtration process. The final effluent, reported to contain about 1% of the influent Pu, was sampled prior to release to Acid Canyon. Until mid-1953, TA-45 treated liquid wastes from only TA-1. Starting in June 1953, additional liquid wastes were piped in from the new TA-3, which included the Chemistry and Metallurgical Research building where plutonium research was done. TA-3 wastes that met a criterion of 330 dpm/L as a two-week average (NBS Handbook 52, Ref. 4) were discharged untreated to Acid Canyon. By December 1953, about 30% of TA-3 waste was released untreated. In September 1953, wastes from the Health Research Laboratory (TA-43) were added to the line coming from TA-3. In 1958, wastes from a new radiochemistry facility (TA-48) were added to the line coming from TA-3. Fission products from this source reportedly caused increased gross beta and gamma content of TA-45 effluent for 1960-63. In July 1963, wastes from TA-3 and TA-48 were redirected to the new TA-50 Central Waste Treatment Plant located south of Los Alamos Canyon. Liquid wastes from TA-43 were redirected to the sanitary sewer. Only wastes from TA-1 were treated at TA-45 from July 1963 until TA-45 ceased operation near the end of May 1964. Some untreated low level liquid wastes from decommissioning of Sigma Building at TA-1 were released until June 1964. These were reportedly the last effluents to Acid Canyon. D&D began October 1966. By July 1967, unrestricted access allowed. [DOE/EV 0005/30, LA-8490-ENV, May 1981].

During WWII, Pu was an extremely valuable commodity. During the late 1940s, two tanks ("The General's Tanks") were buried in the DP area to collect waste plutonium solution. These tanks were immediately adjacent to Area A in a fenced area. At present one of the two 50,000 gallon tanks has been emptied and the second partially emptied of its liquid plutonium nitrate solution. The second tank contains liquid awaiting upgrade of the present waste treatment system because of the nitrate content of the waste is too high for the current system. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" circa Oct. 1979]. The last time wastes were added to one of these tanks was in 1947 [Repository No. 601].

Storage tanks at TA-21 initially stored liquid wastes pending future improvements in the extraction processes. It the late 1940s and early 1950s, it was found that the natural soils and clays at TA-21 were effective in removing radioactive contaminants from the wastes liquids (LANL ER 1991). Absorption beds were then used in which the process effluent was emptied in a trench filled with absorption material consisting of cobble, gravel, and fine sand. These beds were located at MDAs T, U, and V.

By 1952, sufficient progress had been made in research for recovering additional plutonium from waste liquids in order to make reprocessing liquid waste viable. A specially built waste treatment laboratory, Building 35, began reprocessing liquid wastes in 1952. In 1967, waste treatment operations were transferred to a new waste facility, Building 257. Treated liquid wastes from both Buildings 35 and 257 were occasionally discharged to the absorption beds at MDA T until 1967. From 1968 to 1976, wastes were mixed with cement and pumped down asphalt-coated shafts augured between the two absorption beds at MDA T. From 1975 to 1983, transuranic wastes were mixed with cement and pumped into corrugated metal pipes, which were stored in the retrievable storage pit dug between the two absorption beds at MDA T. These wastes were retrieved from 1984 to 1986 and relocated to MDA G (TA-54) (LANL ER 1991).

In 1957, average Sr-90 in TA-35 pilot plant liquid effluent was 31-times tolerance. They say that dilution between TA-35 and the Rio Grande would well exceed the 31 to 1 dilution required. [Repository No.. 114].

They held liquid wastes in four 50,000 gal tanks to let Ba-140 and La-140 decay away for 6 months. Sr-89 and Sr-90 became the major constituent after that. [Repository No. 255; c. 1958].

A new waste treatment plant was placed into operation at TA-35 in 1960. It discharged treated wastes to Ten Site Canyon, a small branch of Mortandad Canyon. [Repository No.. 120] "The incinerator water is dumped into this same canyon just a little further up": [Repository No. 277]. Around Aug 1952, about 2000-3000 gal of "very hot" water was released from Ten Site due to equipment failure. Months later, a request was made to dump 50,000 gal of water containing 1.5 millicurie /L. The canyon was surveyed; they found activity in Mortandad Canyon as far as 3 mi east of Ten Site. Was 300 mr/h at the Ten Site Fence. Water usually soaked into ground within 200 yds of Ten Site. Heavy rains apparently carried activity farther in this case. [Repository No. 277 and others]

TA-50, Waste Management Site: This site is divided into two facility management units, which include managing the industrial liquid and radioactive liquid waste received from Laboratory technical areas and activities that are part of the waste treatment technology effort. Went into operation around July 1963. The Radioactive Liquid Waste Treatment Facility (RLWTF) discharges effluent to Mortandad Canyon. Discharges infiltrate into the stream channel and maintain a saturated zone in the alluvium extending about 3.5 km downstream from the outfall. Continuous surface flow has not reached the Pueblo of San Ildefonso boundary since observations began in the early 1960s. [LANL 1997 Env. Surv. Report].

The stream flow in the upper reach of the canyon is perennial with the release of cooling water from TA-46 and industrial effluents from TA-50. Storm runoff adds to the volume, extending stream flow into the middle and lower reaches of the canyon, both of which are within DOE property. Since hydrologic observations began in 1960, no runoff has reached the Indian Reservation boundary due to the small drainage are of the canyon and the large volume of unsaturated alluvium. Radionuclides are bound by adsorption or ion exchange to the alluvium in the stream channel. The wastewater stream from the TA-50 waste treatment plant contains trace amounts of fluorides, nitrates, sulfates, phosphates, organic materials, and metals, in addition to radioactive residues. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" c. Oct. 1979]

As of 6/20/74, the analytical facilities used for environmental monitoring were located in the basement of TA-50, the waste treatment facility. "It has been a continuing problem to have the contaminated liquid waste processing, our H-1 decontamination facilities, and the low-level environmental analytical chemistry laboratories adjacent to one another." [6/20/74 memo from George L. Voelz to R.E. Schreiber, Deputy Director]

Liquid Waste Disposal at Omega Site –

The streambed and soil of Omega Site are affected from both historical operations there and from releases that occurred upstream. Examples of the latter include discharges from laundry operations at the original Technical Area (TA-1) and an overflow from the industrial waste line that ran through the canyon near the Omega Bridge. The line carried waste from TA-3 to the TA-45 treatment plant. The overflow occurred in January 1955 during attempts to thaw a frozen line (Rep. No. 525). Discharges of liquid effluents from TA-1 included significant amounts of plutonium and polonium.

As of circa 1986, sanitary wastes from both TA-2 and TA-41 facilities were treated at a small treatment plant at TA-41. The effluent liquid from this process was routed to Los Alamos Canyon.

Prior to connection of the TA-2 sanitary waste system to the TA-41 treatment plant (circa. 1974), sanitary wastes went to a local septic tank. The field from this tank discharged to the local soil.

Prior to modifications made in 1963, all radioactive liquid effluents from the OWR deionizers and system waste water were dumped directly to the stream bed (LA-3116). In 1963, a liquid waste storage system was installed that provided for the storage of liquid wastes in three underground tanks. Liquid wastes were held in these tanks for a period of time to allow for radioactive decay. Between 1963 and 1968, the solutions would be diluted as necessary following decay, and then discharged to the stream bed (Rep. No. 648). Early in 1968, a transfer system was installed to allow the solutions to be transferred to portable tanks and then transported by truck to the TA-50 waste management facility. However, Rep. No. 645 (dated August 27, 1973) reports that "numerous" sinks and floor drains still drained non-radioactive liquid wastes to the creek. Rep. No. 515 reports that in 1975, liquid waste from the regeneration of the OWR's ion exchange columns averaged 11,000 liter per month in volume, and that this waste stream represented the most highly radioactive liquid waste generated at TA-2.

A working draft of a Phase 1 CEARP report dated December 1986 (Rep. No. 525) makes reference (via another document) to a surge tank (thought to be TA-2-62) overflowing in 1971. This tank was not one of the liquid effluent holdup tanks.

A draft CEARP Phase I report dated June 27, 1986 (rep. No. 525) states:

> "Environmental sampling started in Los Alamos Canyon in the 1940s to monitor the effluents from TA-1 and TA-2. A 1957 summary mentions that in 1945, fluids in pools in the bottom of the canyon were 20 times the maximum permissible concentration (MPC) for plutonium and 15 times the MPC for polonium in drinking water. In 1946, these values had dropped to 3 times MPC for plutonium. Soil and water samples taken in 1945, 1953, 1954, and 1957 were well below MPC on surface samples and on samples as far as 6 in below the surface. The principal source of the contamination was identified to be the laundry effluents from TA-1. A 1969 memo states that 75 samples had been taken since Nov. 26, 1958 above, at, and below the site in question, including surface water, shallow well, and deep well samples for gross alpha, gross beta, gross gamma, tritium, plutonium-239, plutonium-238, uranium, americium-241, cesium-137, conductance, hexavalent chromium, and zinc. With the exception of hexavalent chromium, which is discharged continuously in effluent water, no concentrations approached published radiological or chemical limits."

The continuous release of hexavalent chromium cited above refers to blowdown discharges from the OWR heat exchangers. Regarding the reference to soil sampling "as far as 6 in below the surface", it is questionable if this was a sufficient depth to fully characterize concentrations of transuranic materials in sedimentary deposits such as a historical flood plain. In general, heavy metals (such as plutonium) will readily percolate through such soils until a less permeable layer is encountered. The material will then begin to accumulate at this depth, forming a placer deposit. Thus, heavy metal concentrations can be significantly higher at deeper depths than at shallow depths.

Another excerpt from the same report (Rep. No. 525) pertaining to impacts from historical operations at TA-1 and TA-2 on the Los Alamos Canyon stream bed states:

> "Environmental monitoring since 1979 has shown that concentrations of plutonium-239 in sediments are elevated downstream from TA-2 when compared with samples taken upstream at the Los Alamos Bridge area. The maximum was in 1982 when 4.1 pCi/g of plutonium-239 was noted, compared with 0.009 pCi/g upstream. In 1983, sampling in the same downstream location resulted in 0.001 pCi/g. Other radionuclide analyses over the years have included Cs-137, Pu-238, gross alpha, gross beta, gross gamma, americium-241, total uranium, Sr-90, and

tritium. Only one data point from these data stands above regional variations in background or fallout ratiation [sic]: 0.39 pCi/g of plutonium-238 at the bridge in 1982."

Historical operations from TA-1, TA-2 and TA-41 have all affected the Los Alamos Canyon stream bed, surface water, and ground water; creating a potential for offsite migration of chemical and radiological pollutants and associated environmental impacts. Local soil and water has been affected by discharges of routine effluents and from leakage from sumps and piping.

Liquid Waste Disposal at TA-21

Storage tanks at TA-21 initially stored liquid wastes pending future improvements in the extraction processes. It the late 1940s and early 1950s, it was found that the natural soils and clays at TA-21 were effective in removing radioactive contaminants from the wastes liquids (LANL ER 1991). Absorption beds were then used in which the process effluent was emptied in a trench filled with absorption material consisting of cobble, gravel, and fine sand. These beds were located at MDAs T, U, and V.

By 1952, sufficient progress had been made in research for recovering additional plutonium from waste liquids in order to make reprocessing liquid waste viable. A specially built waste treatment laboratory, Bldg. 35, began reprocessing liquid wastes in 1952. In 1967, waste treatment operations were transferred to a new waste facility, Bldg. 257. Treated liquid wastes from both Buildings 35 and 257 were occasionally discharged to the absorption beds at MDA T until 1967. From 1968 to 1976, wastes were mixed with cement and pumped down asphalt-coated shafts augured between the two absorption beds at MDA T. From 1975 to 1983, transuranic wastes were mixed with cement and pumped into corrugated metal pipes, which were stored in the retrievable storage pit dug between the two absorption beds at MDA T. These wastes were retrieved from 1984 to 1986 and relocated to MDA G (TA-54) (LANL ER 1991).

Solid Waste Disposal by Burial

Process wastes at TA-21 from the early 1940s until the late 1970s were largely disposed of at five Material Disposal Areas (MDAs). These areas (see Table 5) were known as MDAs A, B, T, U and V (LANL ER 1991).

**Table 5: MDA Descriptions (LANL ER 1991)**

| MDA | Area (acres) | Solid/Liquid Waste Disposal | Brief Description | Date Became Inactive |
|---|---|---|---|---|
| A | 1.25 | Solid | Four pits used 1944 - 1947<br>Large pit used 1969 - 1978 for building D&D<br>Below ground General's tanks used 1945 - 1949 | 1978 |
| B | 6.03 | Solid | Unknown number of pits/trenches used 1945 - 1948<br>Western 2/3 of site paved 1966<br>Eastern 1/3 of site used for trench cover studies 1982 to present | 1952 |
| T | 2.21 | Liquid | Four absorption beds used 1945 - 1967<br>62 shafts for 241Am cement paste disposal used 1968 - 1976<br>TRU cement paste storage 1975 - 1983 | 1983 |
| U | 0.2 | Liquid | Two absorption beds used 1948 - 1968 | 1968 |
| V | 0.88 | Liquid | Three absorption beds used in 1945 - 1961 | 1961 |

Solid wastes from TA-21 were, in general, either buried or incinerated. MDAs A and B accepted buried waste. MDA T accepted transuranic wastes that had been placed in corrugated metal pipes; the pipes could be retrieved at a later time. Debris from the destruction or remodeling of buildings at TA-21 was either buried at MDA A or occasionally pushed over the edge of the mesa south of MDA V, piled up northeast of DP East, or abandoned in other places at TA-21.

Materials Disposal Area B is a waste disposal area located south of DP Road (it was the first common burial ground for radioactive waste at the Lab: Rogers 1977); There are 5-6 disposal areas inside (e.g., absorption beds for old TA-21 laundry). There are photos of foam on top of these beds; this foam ran off into the canyon, and included tritium. Millicurie quantities of transuranics, including americium, are reportedly present [Neely/Elliott on 12/98 tour].

Materials Disposal Area C is located north of Pajarito Road near TA-50 [Rogers 1977]

Filter houses and process exhaust at DP Site were decontaminated and decommissioned in 1996. Workers found "mCi/ft" levels of plutonium in ducts. Found 40,000 pCi/g Pu in an acid sump that is still there.

A portion of Waste Area B along the road going to DP Site is leased to the county, which in turn leases it to individuals for parking recreational vehicles. The area is paved with a blacktop coating Occasionally, cracks develop and the blacktop must be filled. Surveillance of the area indicates that there is no external radiation from the buried wastes. Most of the wastes were alpha emitters. ["Potential Environmental Issues at Los Alamos Scientific Laboratory" circa Oct. 1979]

Materials Disposal Area A is at TA-21: it was the 2$^{nd}$ common burial ground. Materials Disposal Area T, west of Area A at TA-21, has been in use since 1945. Four absorption beds received untreated and treated wastes 1945-1967. Since 1968, treated wastes have been mixed with cement and pumped down shafts augered between the south absorption beds and the north absorption beds.

Though small is size, Area T has received more intensive study from an environmental monitoring viewpoint than any other waste disposal area at the Laboratory. [Rogers 1977].

Materials Disposal Area D is two underground chambers used in 1948 at "Hot Point" at TA-33 [Rogers 1977]. The chambers were contaminated with polonium. All experimentation occurred at least 22 years before 1977.

Materials Disposal Area E is an underground chamber (destroyed in 1950) and 6 pits at "New Hot Point" at TA-33 [Rogers 1977]. The area was in use through 1962.

Process wastes at TA-21 from the early 1940s until the late 1970s were largely disposed of at five Material Disposal Areas (MDAs). These areas were known as MDAs A, B, T, U and V (LANL ER 1991).

LASL did dispose of contaminated trash from Bendix, Eberline, Lovelace Clinic, and the Decontamination Laundry in Santa Fe. AEC told them to discontinue this practice in the early 1960s once commercial radioactive material disposal grounds became available in NY, CT, and NV. [2/15/65 memo T.L. Shipman to R.E. Schreiber]

A fire in "the contaminated dump" on Sept 26, 1945 . As soon as the fire was covered with dirt, the fence posts caused a Zeuto survey meter to go off scale. Next morning 3000 cpm, second morning 500 cpm, and 1000 cpm on a fence post with a Peewee [survey instrument] on September 28 [Repository No. 237]. Another fire was reported on 5/3/1948 in the contaminated dump located on

the DP Site road. [Repository No. 239] Repository No. 261 lists other fires at LASL waste disposal areas.

Incinerators

Contaminated oils and fats from machine shops were reported incinerated in "salamanders" at TA-21; air samples were taken, no atmospheric contamination was observed per Health Protection Survey Report Dec. 4-6, 1967 by Shakin and Davis. Does the Sept. 1990 report on TA-21 SWMUs by J. Nyhan (SWMU Descriptions and Identifications of Data Needs: TA-21 Surface Units Aggregate) indicate otherwise?

There was reportedly an incinerator near the rim of Acid Canyon. Chemical analysis of the ash pile that remains at the site reportedly indicated presence of dioxin and furans [draft data from K. Silver, p. 70].

An incinerator was constructed in late 1950/early 1951 at TA-42. Designed for volume reduction of contaminated trash, it provided storage facilities for liquid radioactive waste. [Repository No.. 120]. The TA-42 incinerator was abandoned in 1970.

Major Decommissioning Activity completed in 1981: "Decommissioning of a plutonium-contaminated incinerator facility" (per Site-Wide EIS, DOE/EIS-0238, Jan '99).

## 2.18 Special Studies

Tritium "Seeding" of Lake MacMillan-

On April 23, 1961 two individuals from H-1 participated with USGS in a project to "seed" Lake MacMillan near Carlsbad NM with tritium. They had 5 containers of H-3 from ORNL, each holding 50 Ci of tritiated water. Release of water from the lake was stopped on April 24; gates were to be kept closed about a week. The purpose of the study was to determine the extent of the Lake McMillan underground Reservoir. Water from the lake seeps through the lake bed into underground waterways and comes to the surface again at various points several miles downstream in the Pecos River. It has been estimated that this underground waterway may be a vast lake more than five miles in diameter. Amt of H-3 added was calculated so that resulting concentrations would be less than $1/500^{th}$ of the level generally and officially regarded as safe and acceptable for any drinking water. Expected less than 0.02 μCi/gal in the lake, with even more dilution once it reaches the underground reservoir. [Repos. No. 144].

The DIRECT COURSE Event-

In 1983 LANL personnel participated in uranium mapping of the impact area from the DIRECT COURSE event at White Sands Missile Range. A General-Purpose Heat Source (GPHS) Radioisotope Thermoelectric Generator (RTG) containing $^{238}U$ to simulate its normal fuel was exposed to the detonation of 609 tons of ammonium nitrate/fuel oil (ANFO). This test was designed to simulate the effects of a space shuttle propellant explosion on a RTG. It was shown that the "D-38" simulated fuel was finely divided and widely dispersed. [Repository No. 710]

Heat Source Testing-

In a joint Los Alamos/Naval Oceans System Command experiment, a vented $^{238}Pu$ General Purpose Heat Source was exposed to the live ocean at San Clemente Island. Apparently LANL was asked to examine the unit after exposure and analyze nearby sediment and sea cucumbers. [Repository No. 712].

# 3. OVERVIEW OF INFORMATION GATHERING TO DATE

The document review effort is approaching one-half complete. The document repositories that have been targets of significant review efforts are:

the LANL Central Records Center,
the TA-35 Environment Safety & Health Records Center, and
the LANL Technical Report Collection.

While review of paper documents at the Central Records Center is over 95% complete, there remains a large volume of records on microfilm and microfiche that must be reviewed. While most of the records at the ES&H center at TA-35 have been reviewed, less than 25% of the reports at the Report Collection have been reviewed to date.

The following statistics are based on data submitted on project team members' activity reports through September 30, 2001:

| | |
|---|---|
| Total Number of Boxes Reviewed: | 14,814 |
| Total Number of Notebook Drawers Reviewed: | 1,427 |
| Total Number of Film Drawers Reviewed: | 359 |
| Total Number of Technical Reports Reviewed: | 37,063 |
| Total Number of Document Summaries Prepared: | 2,746 |

The total number of entries in the project database to-date is 2,671. The distribution among the three categories of relevant information in the full set of documents is now as follows:

| | |
|---|---|
| Category 1 (useful for reconstruction of off-site releases or health effects) | 45% |
| Category 2 (information to confirm off-site releases or health effects) | 40% |
| Category 3 (information about other DOE sites) | 14% |

Document review continues in the LANL Report Collection and the Central Records Center. Review of records held by the Office of the Associate Laboratory Directorate for Nuclear Weapons (ALDNW) has begun, in accordance with a Special Security Plan for that group that was issued in June 2001. Initial review of ALDNW records focused on the contents of the ALDNW vault, a relatively small vault.

Because many more records remain to be reviewed and released, many interviews remain to be conducted, and a significant amount of analysis needs to be done of the relevant records that have been identified, it is important to keep in mind that:

- The historical summary information contained in this document is tentative and subject to change, and

- The information given in this report relative to the prioritization of historical releases from Los Alamos facilities is largely based on LANL summary data, not on independently established estimates of what was released and when it was released.

# 4. EFFLUENT DATA AVAILABILITY

## 4.1 Characterization of LANL Airborne Release Points

Table 6 lists the release points for airborne effluents from at Los Alamos facilities. The primary purpose of this table is to aid analysts in figuring what is what as far as release points go and to tell us where we have gaps in data. Conspicuously absent are release points for TA-1. The practice of the day appears to have been to favor air sampling over sampling airborne effluent streams. We have some air sampling data that were collected on various rooftops in the technical area. That said, they were definitely sampling effluent streams at TA-21 during the same era, so maybe we just have not come across something similar for TA-1 yet. These data might be in the LANL Archives.

## 4.2 Availability of Radionuclide Effluent Data from Technical Areas 3 and 21

Table 7 and Table 8 for are representations of effluent data availability for TA-3 and TA-21, respectively, based on documents obtained to date. These tables reflect information from repository documents with numbers 4, 7, 9, 13, 14, 15, 16, 17, 18, 19, 20, 24, 25, 37, and 38. The two tables summarize only the daily data from these collections, though these documents also include weekly, monthly and annual data. All of the release data in the repository numbers listed above have been cataloged in detail. Daily data (only) are depicted here for example purposes. What 7 and 8 don't convey at present, but will need to in the future, are the release points that either were not operating or did not exist during a given time period. Note that the release points listed in Tables 7 and 8 are not complete for either TA-3 or TA-21 (compare the release points listed in Table 6). Only those release points for which we had at least some information in the identified documents that have been reviewed in detail are included. The effluent data cataloging effort needs to progress further before we decide the best way to represent data availability.

Plutonium released was largely $^{239}$Pu to the 1960s. $^{238}$Pu use increased in the 1960s, until in the late 1960s and early 1970s it constituted more than 50% of the plutonium. Isotopic separations of effluent samples were made beginning in 1972 [Repository No. 253]

LASL reportedly did not discharge any substantial quantities of $^{238}$Pu until 1967. No routine analyses were made to differentiate between $^{238}$Pu and $^{239}$Pu until 1971. At that time, about 80% of the plutonium activity was attributed to $^{238}$Pu. This percentage has continued to increase, and $^{238}$Pu now accounts for about 95% of total plutonium activity. [Repository No. 891; also has approximate isotopic breakdowns of "Pu-238" and "Pu-239"].

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 1 | E-4 | Original Sigma Building (?) | | | | assumed original Sigma Bldg. based on date (1956) |
| 1 | Tuballoy Shop Stack | | | | | Assumed TA-1 for now - could be TA-3 |
| | | | | | | |
| 2 | Omega Stack (Mast) | TA-2-9, on South Mesa, South-Southwest of TA-2 | TA-2-1, OWR and Water Boiler (OER) | Ar-41, mixed fission products (radiogases in particular: Xe-133, Xe-135 et al.) | 845 cfm in 1969. 880 cfm in 1973. Gross volume for 1977 was 1.300E+07 $m^3$. | |
| 2 | Water boiler recombiner blower stack | | | noble gases, Ar-41, Cs-138 | 180 cfm in 1970. | stack is 4" in diameter. |
| 2 | Water boiler valve-house stack | | | noble gases, Ar-41, Cs-138 | 0.4 cfm in 1970. | Flow originates from a 3/8" copper tube. |
| | | | | | | |
| 3 | | TA-3-16 | Van de Graaff (P-9) | tritium | 0.25 cfm in 1969. | vertical Van de Graaff |
| 3 | FE-H-2, became FE-16 circa. 1983. | TA-3-16 | Van de Graaff (P-9) | tritium | | it appears this is a new or additional stack added for the Van de Graaff in 1975. |
| 3 | FE-H-1, became FE-14 circa. 1983. | TA-3-16 | Van de Graaff (P-9) | tritium | | added in 1981. |
| 3 | FE-9 | TA-3-16 | Van de Graaff (P-9) | tritium | | added in 1985. |
| | | | | | | |
| 3 | 2 FLMX-1 (FE-15) | TA-3-29 (CMR Building) | south half of Wing 2 | Pu-238, Pu-239, U-233, U-235, U-238, Np-237, Th-nat., Am-241 (1967 through 1969) | 38,800 cfm in 1970. | |
| 3 | 2 FLMX-2 (FE-14) | TA-3-29 (CMR Building) | north half of Wing 2 | Pu-238, Pu-239, U-233, U-235, U-238, Np-237, Th-nat., Am-241 (1967 through 1969) | 50,000 cfm in 1970. | |
| 3 | 3 FLMX-1 (FE-19) | TA-3-29 (CMR Building) | south half of Wing 3 | Pu-238, Pu-239, U-233, U-235, U-238, Am-241 (1967 through 1969); Pu-238 and Pu-239 (1975) | 40,000 cfm in 1970. | |
| 3 | 3 FLMX-2 (FE-20) | TA-3-29 (CMR Building) | north half of Wing 3 | Pu-239, U-233, U-235, U-238, Am-241 (1967 through 1969) | 34,400 cfm in 1970. | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 3 | 4 FLMX-1 (FE-23) | TA-3-29 (CMR Building) | north half of Wing 4 | U-233, U-235, U-238 (1967 through 1969) | 49,700 cfm in 1970. | |
| 3 | 4 FLMX-2 (FE-24) | TA-3-29 (CMR Building) | south half of Wing 4 | Pu-238, Pu-239, U-233, U-235, U-238, Np-237, Th-nat., Am-241, tritium (1967 through 1969) | 35,150 cfm in 1970. | |
| 3 | 5 FLMX-1 (FE-29) | TA-3-29 (CMR Building) | north half of Wing 5 | Pu-239, U-235, U-238, Np-237, Th-nat., Am-241, tritium (1967 through 1969) | 39,430 cfm in 1970. | |
| 3 | 5 FLMX-2 (FE-28) | TA-3-29 (CMR Building) | south half of Wing 5 | Pu-238, Pu-239, U-235, U-238, Th-nat., Am-241 (1967 through 1969) | 36,800 cfm in 1970. | |
| 3 | 7 FLMX-1 (FE-32) | TA-3-29 (CMR Building) | south half of Wing 7 | Pu-239, U-235, Pu-241 (1967 through 1969) | 33,100 cfm in 1970. | |
| 3 | 7 FLMX-2 (FE-33) | TA-3-29 (CMR Building) | north half of Wing 7 | Pu-238, Pu-239, U-235, Th-nat., Am-241 (1967 through 1969) | 31,400 cfm in 1970. | |
| 3 | Wing 9 Stack 1 | TA-3-29 (CMR Building) | Wing 9 general area | | 47,420 cfm in 1970. | |
| 3 | Wing 9 Stack 2 | TA-3-29 (CMR Building) | Wing 9 general area and hot cells | | 69,020 cfm in 1970. | |
| 3 | Wing 9 Stack 3 | TA-3-29 (CMR Building) | Wing 9 room 9141 and general area | | 60,400 cfm in 1970. | |
| 3 | Wing 9 exhaust stack 2 charcoal filter | TA-3-29 (CMR Building) | | | | |
| 3 | FE-44, FE-45, FE-46 | TA-3-29 (CMR Building) | Wing 9 | Pu-239, U-235 and fission products (including I-131) (1967 through 1969); Pu-239 (1975) | gross volume for 1975 was 26.26E+08 $m^3$. | Same as Wing 9 Stack 1, Stack 2 and Stack 3; but unknown which is which at this time. |
| 3 | Wing 2 roof exhaust | TA-3-29 (CMR Building) Wing 2 | | | | Not the same as the "FLMX" exhaust. |
| 3 | Wing 3 roof exhaust | TA-3-29 (CMR Building) Wing 3 | | | | Not the same as the "FLMX" exhaust. |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 3 | Wing 4 roof exhaust | TA-3-29 (CMR Building) Wing 4 | | | | Not the same as the "FLMX" exhaust. |
| 3 | Wing 5 roof exhaust | TA-3-29 (CMR Building) Wing 5 | | | | Not the same as the "FLMX" exhaust. |
| 3 | Wing 7 roof exhaust | TA-3-29 (CMR Building) Wing 7 | | | | Not the same as the "FLMX" exhaust. |
| 3 | FE-17 | TA-3-29 (CMR Building) Wing 2 | room air - Wing 2 south offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.33E+08 m3. | added in 1975. |
| 3 | FE-18 | TA-3-29 (CMR Building) Wing 2 | room air - Wing 2 north offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.64E+08 m3. | added in 1975. |
| 3 | FE-21 | TA-3-29 (CMR Building) Wing 3 | room air - Wing 3 south offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.48E+08 m3. | added in 1975. |
| 3 | FE-22 | TA-3-29 (CMR Building) Wing 3 | room air - Wing 3 north offices | U-238 and U-235 (1975) | gross volume for 1975 was 0.39E+08 m3. | added in 1975. |
| 3 | FE-26 | TA-3-29 (CMR Building) Wing 4 | room air - Wing 4 north offices | U-238 and U-235 (1975) | gross volume for 1975 was 0.49E+08 m3. | added in 1975. |
| 3 | FE-27 | TA-3-29 (CMR Building) Wing 4 | room air - Wing 4 south offices | U-238 and U-235 (1975) | gross volume for 1975 was 0.37E+08 m3. | added in 1975. |
| 3 | FE-30 | TA-3-29 (CMR Building) Wing 5 | room air - Wing 5 north offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.66E+08 m3. | added in 1975. |
| 3 | FE-31 | TA-3-29 (CMR Building) Wing 5 | room air - Wing 5 south offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.64E+08 m3. | added in 1975. |
| 3 | FE-34 | TA-3-29 (CMR Building) Wing 7 | room air - Wing 7 south offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.64E+08 m3. | added in 1975. |
| 3 | FE-35 | TA-3-29 (CMR Building) Wing 7 | room air - Wing 7 north offices | Pu-238 and Pu-239 (1975) | gross volume for 1975 was 0.65E+08 m3. | added in 1975. |
| 3 | VFE-48 | TA-3-29 (CMR Building) | | | | |
| | | | | | | |
| 3 | FE-52, became FE-26 in 1984. | TA-3-34 (Cryogenics Building B) | | tritium; Pu-238 and Pu-239 (1975) | | |
| | | | | | | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 3 | FE-1 (West, E-2) | west side of SM-35 (Press Building) | 1969: TA-3-35, Room 105 | U-235 (1967, 1969) | 8200 cfm in 1969. 7580 cfm in 1973 | 1969 memo report makes mention of "recent re-vamp" that apparently affected the area exhausted and the flow rate. |
| 3 | FE-2 (West, E-1) | west side of SM-35 (Press Building) | 1969: TA-3-35, Room 104 | U-235 (1967, 1969) | 11,673 in 1969. 9360 cfm in 1973. | 1969 memo report makes mention of "recent re-vamp" that apparently affected the area exhausted and the flow rate. |
| 3 | FE-3 (Southwest, E-3) | through wall on west side of SM-35 (Press Building) | 1969: TA-3-35, Room 101-B | U-235 (1967, 1969) | 2800 cfm in 1969. Not in use in 1973. | 1969 memo report makes mention of "recent re-vamp" that apparently affected the area exhausted and the flow rate. |
| | | | | | | |
| 3 | Stack 1 | Shop 13, Beryllium Shop (TA-3-39) | | Sc-46, Co-60 | | 1966 only? |
| 3 | Stack 2 | Shop 13, Beryllium Shop (TA-3-39) | | Sc-46, Co-60 | | 1966 only? |
| 3 | Stack 3 | Shop 13, Beryllium Shop (TA-3-39) | | Sc-46, Co-60 | | 1966 only? |
| | | | | | | |
| 3 | | South Wing, P-12 cyclotron building | Cyclotron (TA-3-40) | tritium | | As of 1970, emissions from this stack were monitored, but not recorded. Tritium is released when the He-3 trap is out-gassed. |
| 3 | FE-1 | TA-3-40 | Physics Bldg. Cal. Lab | Po-210 (?) | | Same as cyclotron stack? |
| | | | | | | |
| 3 | | SM-65 | SM-65 vault | radon | | Presumably just ventilation of air in the vault - not a process area. |
| | | | | | | |
| 3 | FE-1 (Southeast, E-6) | East side of SM-66 (Sigma Building) | TA-3-66 fabrication section | U-235 and D.U. (1969) | 38,186 cfm (1969). 37,800 cfm in 1973. | |
| 3 | FE-7 (Northwest, E-2 and E-3? - not sure about E-3) | West side of SM-66 (Sigma Building) | TA-3-66 ceramics section | D.U. and $ThO_2$ (1969) | not in use in 1967;17,742 cfm (1969); 23,300 cfm in 1973. | |
| 3 | FE-8 (Northwest, E-1) | West side of SM-66 (Sigma Building) | TA-3-66 foundry section | D.U. (1967, 1969) | 26,461 cfm (1969). 16,800 cfm in 1973. | |
| 3 | FE-9 (Northeast, E-7 and E-4? - not sure about E-4) | East side of SM-66 (Sigma Building) | TA-3-66 powder metallurgy section | U-235 and D.U. (1967, 1969) | 44,436 cfm (1969). 40,800 cfm in 1973. | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 3 | FE-10 (Southeast, E-5) | East side of SM-66 (Sigma Building) | TA-3-66 U-235 foundry and Shop 21 | U-235 (1967, 1969) | 20,189 cfm (1969). 17,500 cfm in 1973. | |
| 3 | FE-13 (North, E-3) | North side of SM-66 (Sigma Building) | TA-3-66 foundry and Graphite Shop | D.U. (1967, 1969); Th-234 (1977) | 39,513 cfm (1969). 35,200 cfm in 1973. | |
| 3 | FE-14 (E-3) | North side of SM-66 (Sigma Building) | TA-3-66 foundry and Graphite Shop | D.U. (1967, 1969) | 39,513 cfm (1969) | |
| 3 | FE-15 (E-3) | North side of SM-66 (Sigma Building) | TA-3-66 foundry and Graphite Shop | D.U. (1967, 1969) | 39,513 cfm (1969) | |
| 3 | FE-24 | Through roof of SM-66 (Sigma Building) over Room G-105 | TA-3-66 Ceramics | D.U. and $ThO_2$ (1969) | not in use in 1967; 2,365 cfm (1969). 2,660 cfm in 1973. | |
| 3 | FE-25 | Through roof of SM-66 (Sigma Building) over Room B-107 | TA-3-66 Foundry | D.U. (1969) | not in use in 1967; 2,549 cfm (1969) | |
| 3 | FE-26 (Northwest corner) | Through roof of SM-66 (Sigma Building) over Room B-107 | TA-3-66 Foundry | D.U. (1969); Th-234 (1977) | not in use in 1967; 2,549 cfm (1969). 260 cfm in 1973. | |
| 3 | FE-27 | Through roof of SM-66 (Sigma Building) over Room B-107 | TA-3-66 Foundry | D.U. (1969); Th-234 (1977) | not in use in 1967; 2,549 cfm (1969). 800 cfm in 1973. | |
| | | | | | | |
| 3 | E-1 (Stack 1) | Shop 15 (TA-3-102) | | U-235, U-238 | | |
| 3 | E-2 (Stack 2) | Shop 15 (TA-3-102) | | U-235, U-238 | | |
| 3 | E-3 (Stack 3) | Shop 15 (TA-3-102) | | U-235, U-238 | | |
| 3 | FE-20 | South side of SM-102 (Shop 15) | TA-3-102 (main stack) | U-235, D.U. (1967, 1969, 1975) | 16,000 cfm (1969). 16,600 cfm in 1973. Gross volume for 1975 was 1.62E+08 $m^3$. | unknown if same as one or all of Stacks 1, 2, or 3. |
| | | | | | | |
| 3 | FE-6 (North, E-1) | North side of SM-141 (Rolling Mill Building) | TA-3-141 Room 148 | D. U. (1967, 1969) | 14,648 cfm (1969). 13,700 cfm in 1973. | |
| 3 | FE-9 (Northwest, E-2) | Through roof of SM-141 (Rolling Mill Building) over Room 136 | TA-3-141 Rooms 150, 144 and 142 | D. U. (1967, 1969) | 18,322 cfm (1969). 18,600 cfm in 1973. | |
| 3 | FE-10 (Southwest, E-3) | Through roof of SM-141 (Rolling Mill Building) over Room 144 | TA-3-141 Rooms 135, 136, 137 and 141 | D. U. (1967, 1969) | 25,868 cfm (1969). 30,200 cfm in 1973. | |
| | | | | | | |
| 9 | FE-3 | TA-9-21 | Room 119 | tritium | 2,704 cfm (1969). 1,900 cfm in 1973. | |
| 9 | FE-4 | TA-9-21 | Room 120 | tritium | 2,731 cfm (1969). 1,620 cfm in 1973. | |

# Table 6: List of Los Alamos Stacks

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| | | | | | | |
| 9 | | TA-9-32 | | | | |
| | | | | | | |
| 18 | FE-1 | | | U-235, MFP | | |
| | | | | | | |
| 20 | | | Cutoff shack | Po-210 | | 1946 only? |
| | | | | | | |
| 21 | East Manifold | | | | | |
| 21 | West Manifold | | | | | |
| 21 | Exhaust 2 (Building 2 exhaust) | | TA-21-2 | | | |
| 21 | Bldg. 2 east stack (FE-2, became FE-1 for TA-21-313(2E) in 1984. | | TA-21-2 room air, changed to TA-21-313(2E) in 1984. | Pu-239 | gross volume for 1975 was 2.78E+08 m3. | |
| 21 | Bldg. 2 west stack (FE-1) | | TA-21-2 room air | Pu-239 | gross volume for 1975 was 3.87E+08 m3. | terminated in 1983. |
| 21 | Exhaust 3 (Building 3 exhaust) | | | | | |
| 21 | Bldg. 3 east stack (FE-2, became FE-1 for TA-21-314(3E) in 1984.) | | TA-21-3 room air, changed to TA-21-314(3E) in 1984. | Pu-238, Pu-239 | gross volume for 1975 was 1.82E+08 m3. | |
| 21 | Bldg. 3 west stack (FE-1, became FE-2 for TA-21-313(3W) in 1984.) | | TA-21-3 room air, changed to TA-21-313(3W) in 1984. | Pu-238, Pu-239 | gross volume for 1975 was 3.34E+08 m3. | |
| 21 | Bldg. 3 main (south) stack (FE-1, Room 313 main process stack?) | | | U-235 (1977) | | |
| 21 | Bldg. 3 Incinerator Stack (FE-1, Room 313 incinerator?, became process area stack TA-21-3(P) in 1984 - retained FE-1 designation). | | | U-235 (1977) | | |
| 21 | Exhaust 4 (Building 4 exhaust) | | | | | |
| 21 | Room 401 stack exhaust | | Room 401 | Pu-239 and fission products (1967) | | Does this refer to the drybox, cell and stack collectively; or is this a separate exhaust entirely? |
| 21 | Bldg. 4 west stack (FE-2, Room 401 drybox?, became FE-7 for TA-21-314(W) in 1984.) | | Bldg. 4 room air, changed to TA-21-314(W) in 1984. | Pu-238 (1973); U-235 (1977) | gross volume for 1975 was 2.66E+08 m3. | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 21 | Bldg. 4 hot cell stack (FE-1, Room 401 cell exhaust) | | TA-21-4 Hot Cell | Pu-239 | gross volume for 1975 was 0.48E+08 m3. | |
| 21 | Bldg. 4 south stack (FE-1, Room 401 stack?, became main stack (FE-3) circa. 1983.) | | | U-235 (1978) | Gross volume for 1978 was 3.120E+08 $m^3$. | |
| 21 | Room 413 main exhaust (NOT same as Room 413 stack!) | | Room 413 | | | |
| 21 | Room 408 and Room 413 main process stack (sometimes reported as just Room 413) | | | | | |
| 21 | Exhaust 5 (Building 5 exhaust) | | | | | |
| 21 | Bldg. 5 east stack (FE-1) | | | Pu-239 | gross volume for 1975 was 3.74E+08 m3. | |
| 21 | Bldg. 5 west stack (FE-2, became FE-1 for TA-21-315(5W) in 1984.) | | TA-21-5 room air, changed to TA-21-315(5W) in 1984. | Pu-239 | gross volume for 1975 was 3.53E+08 m3. | |
| 21 | FE-5/FE-6 | TA-21-5 SR | | Pu-239 | gross volume for 1975 was 0.16E+08 m3. | |
| 21 | FE-1 | | TA-21-5 (Room 530) | Pu-239 | gross volume for 1975 was 0.72E+08 m3. | |
| 21 | | | TA-21-5 (Room 530 Hood) | Pu-239 | gross volume for 1975 was 0.21E+08 m3. | |
| 21 | Bldg. 12 Stack 1 | TA-21-12 (#1) | | Pu-239 | | |
| 21 | Bldg. 12 Stack 2 | TA-21-12 (#2) | | Pu-239 | | |
| 21 | Bldg. 12 Stack 3 | TA-21-12 (#3) | | Pu-239 | | |
| 21 | Bldg. 12 Stack 4 | TA-21-12 (#4) | | Pu-239 | | |
| 21 | | | Building 20 (Laundry) | Pu-239, U-235, U-238, Po-210 | | |
| 21 | | | Building 21 (Vault) | Pu-238, Pu-239, U-233, U-235 | | |
| 21 | | | Building 33 (waste treatment lab) | Pu-239, Sr-89, Sr-90 | | |
| 21 | | | Building 35 (waste disposal lab) | Pu-239, U-235, U-238, Cm-244 | | |
| 21 | | | Building 61 | U-235 | | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 21 | Building 146 | Building 146 | Building 2 only? - appears to be upstream of the other buildings. | Pu, U, Am, Cm, Ac, Pa | | Appears that 1959 was the first year this facility operated. Not clear if this was a discharge point or just a filtration stage prior to the Building 12 stacks. |
| 21 | Building 150 room air exhaust (FE-1) | TA-21-150 | Bldg. 150 room air | Pu-238, Pu-239 | gross volume for 1975 was 2.83E+08 m3. | |
| 21 | FE-4 | | TA-21-257 | Am-241 (1978); Pu-239 (1981) | | added in 1978. |
| 21 | FE-6 | | TA-21-257 (Pug Mill) | | | terminated in 1983. |
| 21 | TA-21-324 Process Exhaust (FE-1/FE-2: FE-2 became FE-1 in 1984.) | | | Pu-238, Pu-239 | gross volume for 1975 was 2.02E+08 m3. | |
| | | | | | | |
| 21 | DP East Bldg. 152 | | | Po-210, U-235, Ac-227, Th-232 | | |
| 21 | DP East (Bldg. 153) Stack 1 | | | | | |
| 21 | DP East (Bldg. 153) Stack 2 | | | | | |
| 21 | DP East Bldg. 155 NE | TA-21-155 NE | | U-235 | gross volume for 1975 was 0.57E+08 m3. | this release point was terminated in 1977. |
| 21 | DP East Bldg. 155 NW | TA-21-155 NW | | U-235 | gross volume for 1975 was 0.44E+08 m3. | this release point was terminated in 1977. |
| 21 | DP East Bldg. 155 SE | TA-21-155 SE | | U-235 | gross volume for 1975 was 0.46E+08 m3. | this release point was terminated in 1977. |
| 21 | DP East Bldg. 155 SW | TA-21-155 SW | | U-235 | gross volume for 1975 was 0.59E+08 m3. | this release point was terminated in 1977. |
| 21 | FE-5 | TA-21-155 North | TSTA | | | added in 1984. |
| 21 | FE-10, became FE-1,-10,-12 in 1984. | | TA-21-209 (DP East) | | | added in 1975. |
| | | | | | | |
| 32 | | | Medical research lab | Pu-239 | | |
| | | | | | | |
| 33 | FE-6/FE-11, became FE-6-11 in 1984. | TA-33-86 (main stack) | Cleaning hood and Room 9 | tritium | 4,096 cfm (1969). 5,730 cfm in 1973. | |
| 33 | FE-8 | TA-33-86 (main stack) | Cleaning hood and Room 9 | tritium | 4,096 cfm (1969) | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| | | | | | | |
| 35 | FE-2 (South, E-10) | South-southwest corner of Building 7 | Rooms 127, 129, 131, 133, 135, 137, 139, 141, 143, 145, 155 | Pu-239 and U-235 (1967, 1969) | 15,600 cfm (1969). 8,080 cfm in 1973. Gross volume for 1975 was 1.67E+08 $m^3$. | |
| 35 | FE-3 (Northeast corner, E-11) | East of Building 7 | Rooms 164 (Lab C), 165 and 166 | Pu-239 (1967, 1969) | 8,267 cfm (1969). 9,330 cfm in 1973. Gross volume for 1975 was 1.87E+08 $m^3$. | terminated in 1980. |
| 35 | FE-4 (E-13?) | | | | 3,030 cfm in 1973. | Assumed same as E-13, but this needs to be confirmed. |
| 35 | FE-6 (Northeast, E-14) | East of Building 7 | Room 161 (Lab C) | Pu-239 (1967, 1969) | 4,050 cfm (1969). 3,530 cfm in 1973. Gross volume for 1975 was 0.48E+08 $m^3$. | terminated in 1980. |
| 35 | FE-7 (Southeast, E-15) | East of Building 7 | Room 162 (Lab B) | Pu-239 (1967, 1969) | 2,308 cfm (1969). 2,990 cfm in 1973. Gross volume for 1975 was 0.43E+08 $m^3$. | |
| 35 | Pu labs drybox exhaust (FE-8, Southeast Corner or Southeast Central) | Out of Building 2 | Drybox trains and hoods in Rooms 129, 133, 134, 137, 139, 140, 144 and 161 | Pu-239 (1967, 1969) | 3,142 cfm (1969). 2,170 cfm in 1973. Gross volume for 1975 was 0.40E+08 $m^3$. | |
| 35 | Lab A exhaust | | Lab A | | | Definitely co-existed with E-10, E-11, E-13, E-14, E-15, and Pu labs exhaust - not redundant with any of these. |
| 35 | FE-11 | TA-35-2 South | | tritium | 9,200 cfm in 1973. Gross volume for 1977 was 1.104E+08 $m^3$. | terminated in 1979. |
| 35 | FE H-1 | TA-35-2 | | | | added in 1980. terminated in 1984. |
| 35 | FE-1 | TA-35-213 | Target Fab. Facility | | | |
| 35 | FE-5 | TA-35-213 | Target Fab. Facility | | | |
| | | | | | | |
| 41 | FE-2 | | | | 490 cfm in 1973 | emergency use only per 1973 stack air flow measurements memo. |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 41 | tritium gas sample duct feeder | TA-41-4 | | | 3,560 cfm in 1973. | this and FE-17 are one stack. Is this FE-4 perhaps? FE-4 became FE-17 circa. 1983. |
| 41 | FE-17 | West end of Building 4 (TA-41-4) | All of W-7 area | Pu-238, Pu-239, U-235 (1967, 1969); tritium | 25,338 cfm (1969). 25,000 cfm in 1973. | |
| | | | | | | |
| 42 | | TA-42-1 | TA-42-1 incinerator | Pu-239, Am-241 (1969) | 300 cfm (1969) | |
| | | | | | | |
| 43 | | Roof of HRL | HRL Room B-128 | Pu-238 (1969) | | presume this is redundant with one of the FE stacks below, however, it is unknown which one. |
| 43 | FS-15 | TA-43-1 | | Pu-239 | | not known if same as FE-15 |
| 43 | FE-15 | TA-43-1 | | | 4,590 cfm in 1973. | FE-15, FE-16, FE-17 and an unknown FE# all feed a common stack per the 1973 stack air flow measurements report. The flow rate for the unknown FE# designation was 4,000 cfm. |
| 43 | FE-16 | TA-43-1 | | | 2,930 cfm in 1973. | FE-15, FE-16, FE-17 and an unknown FE# all feed a common stack per the 1973 stack air flow measurements report. The flow rate for the unknown FE# designation was 4,000 cfm. |
| 43 | FE-17 | TA-43-1 | | | 550 cfm in 1973. | FE-15, FE-16, FE-17 and an unknown FE# all feed a common stack per the 1973 stack air flow measurements report. The flow rate for the unknown FE# designation was 4,000 cfm. |
| 43 | FE-24 | TA-43-1 | | Pu-239; P-32 (1977) | 230 cfm in 1973. Gross volume for 1975 was 0.05E+08 $m^3$. | |
| 43 | FE-9 | TA-43-1 | | Pu-238 and Pu-239 (1975); P-32 (1977) | 12,100 cfm in 1973. Gross volume for 1975 was 1.77E+08 $m^3$. | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 43 | FE-10 | TA-43-1 | | Pu-239 (1975); P-32 (1977) | Gross volume for 1975 was 1.47E+08 $m^3$. | |
| 43 | FE-11, became FE-12 circa. 1983. | TA-43-1 | | Pu-239 (1975); P-32 (1977) | Gross volume for 1975 was 2.61E+08 m3. | |
| 43 | FE-12, became FE-34 circa. 1983. | TA-43-1 | | Pu-239 (1975); P-32 (1977) | Gross volume for 1975 was 2.58E+08 m3. | |
| 43 | FE-14 | TA-43-1 | | Pu-239 (1975); P-32 (1977) | | looks like combined with FE-16 and FE-17 at some point, or may have always been that way. |
| | | | | | | |
| 45 | | | Lab building | Pu-239, Sr-90 | | |
| | | | | | | |
| 46 | FE-11 (Room 8) | TA-46-1 | Room 8 | U-235 | 1,130 cfm in 1973. | |
| 46 | | TA-46-31 | Room 170 | U-235 (1969) | varies depending on test - prescribed by H-5 | |
| 46 | FE-36 | TA-46-31 | | U-235 | 1,300 cfm in 1973. | may be same as for TA-46-31 Room 170 above. |
| 46 | FE-37 | TA-46-31 | | U-235 | 1,750 cfm in 1973. | may be same as for TA-46-31 Room 170 above. |
| 46 | | TA-46-16 | Test Cell 1 and 4 (2 stacks) | U-235 (1969) | varies depending on test - prescribed by H-5. TC-I was asserted at 560 cfm in 1973 and TC-IV was asserted at 750 cfm. | |
| 46 | FE-25 (South) | TA-46-31 | | U-238 (1977) | Gross volume for 1977 was 2.676E+06 $m^3$. | |
| 46 | FE-26 (Southwest) | TA-46-31 | | U-235 (1977) | Gross volume for 1977 was 5.096E+06 $m^3$. | |
| 46 | FE-41 (North) | TA-46-31 | | U-238 (1977) | Gross volume for 1977 was 3.648E+05 $m^3$. | |
| 46 | FE-44 (West Stack) | TA-46-31 | | U-238 (1977) | Gross volume for 1977 was 1.368E+05 $m^3$. | added in 1975. |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 46 | FE-43, became FE-41 circa. 1983. | TA-46-31 | | U-238 (1978) | Gross volume for 1978 was 1.240E+07 $m^3$. | added in 1978. |
| | | | | | | |
| 48 | FE-11 (East Fan Feeder - South side of building) | South side of building | Southeast section of building | Uranium and fission products (1969) | 21,028 cfm (1969). 22,000 cfm in 1973. | Feeder lines FE-11, FE-12 and FE-13 fed into a common stack located at the south end of the building. In 1984, FE-11, FE-12 and FE-13 became FE-11 (only). |
| 48 | FE-12 (West Fan Feeder - South side of building) | South side of building | Southwest section of building | Uranium and fission products (1969) | 15,574 cfm (1969). 19,900 cfm in 1973. | Feeder lines FE-11, FE-12 and FE-13 fed into a common stack located at the south end of the building. In 1984, FE-11, FE-12 and FE-13 became FE-11 (only). |
| 48 | FE-13 (Center Fan Feeder - South side of building) | South side of building | Old dissolving rooms | Uranium and fission products (1969) | 15,699 cfm (1969). 17,900 cfm in 1973. | Feeder lines FE-11, FE-12 and FE-13 fed into a common stack located at the south end of the building. In 1984, FE-11, FE-12 and FE-13 became FE-11 (only). |
| 48 | FE-15 (East fan feeder - North side of building) | North side of building | Northeast section of building | Pu-239 and fission products (1969) | 24,432 cfm (1969). 27,600 cfm in 1973. | Feeder lines FE-15 and FE-16 fed into a common stack located at the north end of the building. In 1984, FE-15 and FE-16 were designated FE-15 (only). |
| 48 | FE-16 (West fan feeder - North side of building) | North side of building | Northwest section of building | Pu-239 and fission products (1969) | 21,368 cfm (1969). 20,700 cfm in 1973. | Feeder lines FE-15 and FE-16 fed into a common stack located at the north end of the building. In 1984, FE-15 and FE-16 were designated FE-15 (only). |
| 48 | FE-18 | | | | | added in 1980. |
| 48 | FE-37 Feeder Line | North side of building | Hot cells on north side | Uranium and fission products (1969) | 2,800 cfm (1969). Not in use in 1973. | Feeder lines FE-37, Fe-38, FE-39 and FE-40 feed into a common stack on the north side of the building. |
| 48 | FE-38 Feeder Line | North side of building | Hot cell personnel area | Uranium and fission products (1969) | 3,120 cfm (1969). 3,556 cfm in 1973. | Feeder lines FE-37, Fe-38, FE-39 and FE-40 feed into a common stack on the north side of the building. In 1984, FE-38 and FE-40 were designated as FE-40 (only). |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 48 | FE-39 Feeder Line | North side of building | Hot cell on north side of building | Uranium and fission products (1969) | 3,120 cfm (1969). Not in use in 1973. | Feeder lines FE-37, Fe-38, FE-39 and FE-40 feed into a common stack on the north side of the building. |
| 48 | FE-40 Feeder Line | North side of building | Hot cell personnel area | Uranium and fission products (1969) | 2,800 cfm (1969). 1,930 cfm in 1973. | Feeder lines FE-37, Fe-38, FE-39 and FE-40 feed into a common stack on the north side of the building. In 1984, FE-38 and FE-40 were designated as FE-40 (only). |
| 48 | FE-45 (Core Wing) | TA-48-1 | | | 24,000 cfm in 1973. | FE-45 and FE-46 feed a single stack per the 1973 air flow measurements memo. |
| 48 | FE-46 (Core Wing) | TA-48-1 | | | 21,500 cfm in 1973. | FE-45 and FE-46 feed a single stack per the 1973 air flow measurements memo. |
| 48 | FE-51 (Alpha Wing) | TA-48-1 | | | 630 cfm in 1973. | |
| 48 | FE-54 (Northeast) | TA-48-1 | | Pu-239 (1978) | | |
| | | | | | | |
| 50 | FE-1 (Northeast) | Northeast side of building TA-50-1 | Rooms 10 and 11; Size Reduction Facility Room (1982) | mostly Pu-239 (1967, 1969) | 20,945 cfm (1969). 26,200 cfm in 1973. | |
| 50 | FE-2 (Southeast) | Southwest corner of building TA-50-1 | Rooms 24, 34, 35, 36 116, 123, 130 and 131. | mostly Pu-239 (1967, 1969) | 44,150 cfm (1969). 35,600 cfm in 1973. | |
| 50 | FE-3 (South) | Southeast side of building TA-50-1 | Rooms 38 and 38-A; Size Reduction Facility Process (1982) | mostly Pu-239 (1969) | not in use in 1967; 3,712 cfm (1969). 2,800 cfm in 1973. | |
| 50 | FE-4, became FE-25 in 1984. | TA-50-1 | | | | |
| 50 | FE-6 | TA-50-1 | Retrievable waste pre-treatment Am-241 plant | | | added in 1983. |
| 50 | FE-18, became FE-17 circa. 1983. | TA-50-1 | | | | |
| 50 | FE-27 | TA-50-1 | New decon. area | | | added in 1983. |
| 50 | FE-1 (TDF) | TA-50-37 | | | Gross volume in 1980 was 3.300E+07 $m^3$. | |
| | | | | | | |
| 52 | | TA-52-1, north side | UHTREX reactor | fission products, I-131, trace U-235 (1969) | 21,025 cfm (1969) | |
| | | | | | | |

**Table 6: List of Los Alamos Stacks**

| Technical Area | Stack/Vent Designation | Location | Areas Exhausted | Type of Material | Flow Information | Remarks |
|---|---|---|---|---|---|---|
| 53 | FE-3 (North Stack) | | | C-11, N-13, O-15, Ar-41, Be-7 (1977) | Gross volume for 1977 was 2.650E+06 $m^3$. Gross volumes of 1.528E+08 $m^3$ and 1.694E+08 $m^3$ are reported for 1977. | terminated in 1980. |
| 53 | FE-4 (South Stack) | | | | Gross volume for 1977 was 1.713E+06 m3. | added in 1977. |
| 53 | FE-16 | TA-53-1 D-wing | | Be-7 | Gross volume for 1977 was 1.992E+08 m3. | |
| 53 | FE-2 | WNR | | | | added in 1981. |
| | | | | | | |
| 54 | FE-1 | Main Stack, became room exhaust circa. 1983. | | Pu-239 | Gross volume for 1978 was 2.809E+06 $m^3$. | added in 1977. |
| 54 | FE-2 | room air exhaust, became process exhaust circa. 1983. | | | Gross volume for 1978 was 7.950E+06 $m^3$. | added in 1978. |
| | | | | | | |
| 55 | FE-15 (North Stack) | | | Pu-239 | Gross volume for 1978 was 2.483E+08 $m^3$. | added in 1978. |
| 55 | FE-16 (South Stack) | | | Pu-239 | Gross volume for 1978 was 3.198E+08 m3. | added in 1978. |

# Table 7: Summary of Daily Stack Monitoring Data for TA-3

**Daily Data for TA-3 release points: Repository numbers 4 and 7**

| Building Number | Facility | Release Point | Jan-64 | Feb-64 | Mar-64 | Apr-64 | May-64 | Jun-64 | Jul-64 | Aug-64 | Sep-64 | Oct-64 | Nov-64 | Dec-64 | .... | Nov-65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TA-3-35 | Press Building | Stack 1 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-35 | Press Building | Stack 2 | NO | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-35 | Press Building | Stack 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | | YES |
| TA-3-39 | Shop 13 | Stack 1 | NO | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | NO | | YES |
| TA-3-39 | Shop 13 | Stack 2 | NO | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | NO | | YES |
| TA-3-39 | Shop 13 | Stack 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | | YES |
| TA-3-66 | Sigma Building | E-1 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-66 | Sigma Building | E-3 | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-66 | Sigma Building | E-5 | YES | NO | YES | YES | YES | NO | YES | YES | YES | YES | YES | NO | | NO |
| TA-3-66 | Sigma Building | E-6 | YES | NO | YES | YES | YES | NO | NO | NO | NO | NO | NO | NO | | NO |
| TA-3-66 | Sigma Building | E-7 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | | YES |
| TA-3-102 | Shop 15 | Stack 1 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-102 | Shop 15 | Stack 2 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-102 | Shop 15 | Stack 3 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES |
| TA-3-141 | Rolling Mill | E-1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | | YES |
| TA-3-141 | Rolling Mill | E-2 | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | | YES |
| TA-3-141 | Rolling Mill | E-3 | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | | YES |

# Table 8: Summary of Available Daily Stack Monitoring Data for TA-21

**Daily Data for TA-21 release points: Repository numbers 24, 25, 37 and 38 (1945 to 1950)**

| Building Number | Facility | Release Point | Jan-45 | Feb-45 | Mar-45 | Apr-45 | May-45 | Jun-45 | Jul-45 | Aug-45 | Sep-45 | Oct-45 | Nov-45 | Dec-45 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DP West | East Manifold | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | DP West | West Manifold | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-2 | DP West | Exhaust 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| TA-21-3 | DP West | Exhaust 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| TA-21-4 | DP West | Exhaust 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| TA-21-5 | DP West | Exhaust 5 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 1 | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES |
| TA-21-153 | DP East | Bldg. 153 Stack 2 | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES |

| Building Number | Facility | Release Point | Jan-46 | Feb-46 | Mar-46 | Apr-46 | May-46 | Jun-46 | Jul-46 | Aug-46 | Sep-46 | Oct-46 | Nov-46 | Dec-46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DP West | East Manifold | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | DP West | West Manifold | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-2 | DP West | Exhaust 2 | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES |
| TA-21-3 | DP West | Exhaust 3 | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES |
| TA-21-4 | DP West | Exhaust 4 | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES |
| TA-21-5 | DP West | Exhaust 5 | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 1 | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 3 | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES |
| TA-21-153 | DP East | Bldg. 153 Stack 1 | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 2 | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

## Table 8: Summary of Available Daily Stack Monitoring Data for TA-21

| Building Number | Facility | Release Point | Jan-47 | Feb-47 | Mar-47 | Apr-47 | May-47 | Jun-47 | Jul-47 | Aug-47 | Sep-47 | Oct-47 | Nov-47 | Dec-47 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DP West | East Manifold | NO | NO | NO | NO | NO | NO | YES | YES | NO | NO | NO | NO |
| | DP West | West Manifold | NO | NO | NO | NO | NO | NO | YES | YES | NO | NO | NO | NO |
| TA-21-2 | DP West | Exhaust 2 | NO | NO | YES | YES | NO | NO | YES | YES | YES | NO | NO | NO |
| TA-21-3 | DP West | Exhaust 3 | NO | NO | YES | YES | NO | NO | YES | YES | YES | NO | NO | NO |
| TA-21-4 | DP West | Exhaust 4 | NO | NO | NO | NO | NO | NO | YES | YES | YES | NO | NO | NO |
| TA-21-5 | DP West | Exhaust 5 | NO | NO | NO | NO | NO | NO | YES | YES | YES | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 1 | NO | NO | NO | NO | YES | NO | YES | YES | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 2 | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 3 | | | | | | | | | | | | |
| TA-21-12 | DP West | Bldg. 12 Stack 4 | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

| Building Number | Facility | Release Point | Jan-48 | Feb-48 | Mar-48 | Apr-48 | May-48 | Jun-48 | Jul-48 | Aug-48 | Sep-48 | Oct-48 | Nov-48 | Dec-48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DP West | East Manifold | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES | YES |
| | DP West | West Manifold | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES | YES |
| TA-21-2 | DP West | Exhaust 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-3 | DP West | Exhaust 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-4 | DP West | Exhaust 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-5 | DP West | Exhaust 5 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 1 | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 2 | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 3 | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 4 | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES | YES |
| TA-21-153 | DP East | Bldg. 153 Stack 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

# Table 8: Summary of Available Daily Stack Monitoring Data for TA-21

| Building Number | Facility | Release Point | Jan-49 | Feb-49 | Mar-49 | Apr-49 | May-49 | Jun-49 | Jul-49 | Aug-49 | Sep-49 | Oct-49 | Nov-49 | Dec-49 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DP West | East Manifold | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| | DP West | West Manifold | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| TA-21-2 | DP West | Exhaust 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-3 | DP West | Exhaust 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-4 | DP West | Exhaust 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-5 | DP West | Exhaust 5 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 1 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 2 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 3 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| TA-21-12 | DP West | Bldg. 12 Stack 4 | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| TA-21-153 | DP East | Bldg. 153 Stack 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

| Building Number | Facility | Release Point | Jan-50 | Feb-50 | Mar-50 | Apr-50 | May-50 | Jun-50 | Jul-50 | Aug-50 | Sep-50 | Oct-50 | Nov-50 | Dec-50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DP West | East Manifold | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | NO |
| | DP West | West Manifold | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | NO |
| TA-21-2 | DP West | Exhaust 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-3 | DP West | Exhaust 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-4 | DP West | Exhaust 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-5 | DP West | Exhaust 5 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 1 | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 2 | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 3 | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | NO |
| TA-21-12 | DP West | Bldg. 12 Stack 4 | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| TA-21-153 | DP East | Bldg. 153 Stack 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

## 4.3 Availability of Radionuclide Effluent Data from Technical Area 2 (Omega Site)

Operation of the three versions of the Water Boiler reactor (LOPO, HYPO and SUPO) and the Omega West Reactor (OWR) produced routine airborne radionuclide releases from Omega Site from 1944 through 1992. Airborne emissions from the Water Boiler (which was deactivated in 1974) consisted primarily of fission gases and their particulate decay products. However, the Water Boiler gaseous effluent stream also contained smaller amounts of volatile fission products such as $^{131}I$ and $^{137}Cs$.

Releases from the OWR consisted primarily of $^{41}Ar$, which was created via neutron activation of air in the reactor's thermal column region. However, some H-division records make mention of occasional (non-quantified) releases of activated material through the OWR's roof vents. It was also necessary to periodically purge fission gases from the OWR.

The OWR facility included numerous exhaust fans that were used intermittently to ventilate fumes associated with infrequent activities such as resin regeneration, welding, painting, etc. The OWR cooling tower was a persistent source of airborne releases of hexavalent chromium until aluminum components of the tower were replaced with stainless steel in the early 1970s. The aluminum components were replaced so that the use of potassium dichromate as a corrosion inhibitor could be discontinued and thus eliminate the primary source of the chromium VI releases.

Several H-division progress reports make mention of high local airborne radioactivity levels at Omega Site resulting from the loss of normal ventilation equipment due to power failures.

<u>Off-Site impacts associated with operation of the Water Boilers</u>

Rep. No. 2287 describes two problems associated with the sampling of work area air at the Water Boiler (SUPO) facility. The first was a realization that the filter paper being used for sampling failed to pick up gas in the air, meaning the activity concentrations only accounted for particulate matter. The second was that the H-1 group did not have a direct method (instrument) for determining dose rates from sources containing high-energy beta emitters (such as the Water Boiler fuel solution). While these observations pertain specifically to assessments being made for occupational radiation protection purposes, they may also have implications for sampling performed to determine activity concentrations in effluent streams during this era (circa. 1951).

The insensitivity of the filter paper used to collect room air samples to gaseous activity is expounded upon in Rep. No. 2289, which states that "fission product gas given off from the Omega Water Boiler may be a thousand times higher in air concentration than was first indicated by the filter paper method."

(The principal reference for this section is LAMS-2937, "Radioactive Gaseous Effluents From A Homogeneous Reactor", Hankins, 1963)

At the time LAMS-2937 was written, the Water Boiler was operated with a maximum operating power of 25 kW, with the integral power averaging 1000 kWh per month. The temperature of the Water Boiler fuel solution was maintained at 60 C. The reactor vessel was maintained at a negative pressure of about 3 inches of water. Fission products were carried to the air space above the fuel solution by the migration of radiolysis gases through the fuel. A recombiner was used to remove the hydrogen from the gases that collected above the fuel solution. The water created by the recombiner was returned to the reactor vessel, and the remaining radioactive, gaseous effluent was discharged via the stack.

The stack effluent was sampled using a combination of filter papers, charcoal cartridges, and gas samples. Sampling was performed via a 1-inch diameter pipe that was flush with the inside of the stack. An isokinetic sampling probe was not used given the small particle sizes and the fact that the effluent was primarily gaseous. Samples were analyzed via a 3-inch by 3-inch NaI detector and a 400 channel MCA. The energy range covered was about 60 keV to 2000 keV. The fact that several of the photon energies of interest occurred in the region of 80 keV to 250 keV degraded the accuracy of the results. It is stated that the results given are probably good to within a factor of two. Decay corrections for the elapsed time between sampling and counting were made for $^{88}$Rb and $^{138}$Cs. It is stated this delay normally ranged from 8 to 30 minutes.

Around early 1964, the Omega stack monitor was modified to report the output of the stack in curies. In order to reduce the background, it was necessary to move the stack monitor building away from the stack. This proved more effective than was expected. A flow of 5 L/min will be drawn from the stack and diluted with about 200 L/min of clean air. This procedure still requires placing three lead plugs in front of the particulate monitor crystal to reduce the count rate to give a factor of about 20-times above the normal release before pegging both the gas and particulate monitors. The factor of 20 is the emergency capability of the monitor; however, the area monitor at the stack will provide adequate emergency capability. [Repository No. 72]

The isotopes identified in effluent from the Omega Stack consisted of $^{41}$Ar (from the OWR), $^{85m}$Kr, $^{87}$Kr, $^{88}$Kr, $^{88}$Rb, $^{131}$I, $^{133}$Xe, $^{135}$Xe, and $^{138}$Cs. The noble gas and $^{88}$Rb concentrations were found to follow the reactor power history with a lag of about 10 hours (from the delay in the vent line). The $^{131}$I concentration was found to be nearly constant, which was considered to be indicative that most of the iodine created by the reactor was retained in the system and not released. (The report also mentions $^{131}$I and $^{137}$Cs being found in the condensate collected from the vent line.) The $^{138}$Cs concentration in the stack effluent was found to peak prior to the arrival of the remainder of the constituent species. The researchers were unable to explain this phenomenon.

Table 9 summarizes the conclusions from LAMS-2937 regarding the composition of the effluent from the Omega Stack.

**Table 9: Omega Stack Effluent**

| Nuclide | Conc. in stack (μCi/cc) | Curies per 24 hours | Activity Fraction |
|---|---|---|---|
| $^{41}$Ar | $1x10^{-4}$ | 3.8 | 0.022 |
| $^{85m}$Kr | $1x10^{-3}$ to $1x10^{-2}$ | 27 | 0.156 |
| $^{88}$Kr | $1x10^{-3}$ to $1x10^{-2}$ | 21 | 0.121 |
| $^{88}$Rb | $1x10^{-3}$ to $1x10^{-2}$ | 38 | 0.220 |
| $^{131}$I | $1x10^{-9}$ to $1x10^{-8}$ | -- | -- |
| $^{133}$Xe | $1x10^{-4}$ to $1x10^{-3}$ | 4.1 | 0.024 |
| $^{135}$Xe | $1x10^{-3}$ to $1x10^{-2}$ | 79 | 0.457 |
| $^{138}$Cs | $1x10^{-6}$ | -- | -- |

All of the concentration values above represent averages, with the exception of that for the $^{138}$Cs, which is a peak concentration. The highest concentration observed for any radionuclide during the characterization period was $1.5x10^{-2}$ μCi/cc for $^{135}$Xe. The "curies per 24 hours" values given in the table sum to 173 curies. These values correspond to 24 hours of operation at an integral power of 150 kWh with little initial activity in the system (i.e., after a couple days of shutdown). It is asserted that

the curie output would increase by 60 to 70 percent following consecutive days of reactor operation at 150 kWh. Note that at the time this report was compiled, the OWR operated at a power level of about 5 MW.

Another document that provides some indication of the activity associated with the gaseous effluent from the Water Boiler (SUPO) is Rep. No. 2414, which reports that when the vent line from the Water Boiler to the Omega stack was cut to tie in the effluent line from the OWR, the gas released from the cut produced an exposure rate of 80 R/hr. This rate persisted for about 30 minutes, then gradually dissipated. The stack blower was turned on in an effort to accelerate the removal of the gas. All personnel were evacuated until the gas was removed.

Emissions from the Water Boiler valve house & recombiner blower

Rep. No. 1403 includes a memo from Dale Hankins to J. N. P. Lawrence (H-1 associate group leader) dated February, 1970 that describes a characterization of radionuclides and their concentrations in the stack effluents from the water boiler (SUPO) valve house and recombiner blower. The sampling was performed using filter papers, charcoal, and gas samples. The reactor power was 25 kW and it is stated that ample time was allowed between startup and sampling to allow maximum activity to build in.

The stack for the recombiner blower exhausted air at 180 cfm at a velocity of 2000 fpm. The stack diameter was 4 inches. The nuclides found in the recombiner blower effluent were reported to be $^{135}$Xe and $^{138}$Cs. $^{135}$Xe was reported at a concentration of $6.7 \times 10^{-6}$ μCi/cc. The $^{138}$Cs concentration was reported to be $2.7 \times 10^{-7}$ μCi/cc. The corresponding MPCs (occupational, 40 hour week) for that era for these two nuclides were $4 \times 10^{-6}$ μCi/cc for $^{135}$Xe and $1 \times 10^{-6}$ μCi/cc for $^{138}$Cs. Thus, the $^{135}$Xe concentration in the recombiner blower stack exceeded the applicable MPC. The characterization of the recombiner blower effluent was performed on January 12, 1970.

The "stack" for the water boiler valve house was a 3/8 inch diameter copper tube that exhausted air at 0.4 cfm at a velocity of 350 fpm. Radionuclides reported for this effluent stream were $^{41}$Ar, $^{88}$Rb, $^{135}$Xe, $^{138}$Xe, and $^{138}$Cs. The concentrations of $^{135}$Xe and $^{138}$Xe are said to have been too small to be quantified. The $^{41}$Ar concentration was reported as $4.5 \times 10^{-5}$ μCi/cc, over 20 times the occupational MPC of that era ($2.0 \times 10^{-6}$ μCi/cc). The $^{138}$Cs and $^{88}$Rb concentrations were reported as $1.1 \times 10^{-10}$ μCi/cc and $2.9 \times 10^{-10}$ μCi/cc, respectively. Both of these values are several orders of magnitude below their applicable occupational MPC ($1.0 \times 10^{-6}$ μCi/cc). The characterization of the valve house effluent was performed on February 11, 1970.

Regarding the findings that the Xe-135 concentration in the recombiner blower stack and the $^{41}$Ar concentration in the valve house stack exceeded their applicable occupational MPCs, the author concluded that since the stacks were located a significant distance above the building and their outputs were small, "no hazard to personnel on- or off-site exists from the output of these stacks."

Rep. No. 2370 (January, 1955) reports that the exhaust filter for the "penthouse" was found to be plugged and was therefore removed due the large increase in local background that resulted. The "penthouse" exhaust system was modified so that it exhausted through a stack nine feet above the roof level. No filter was used after this modification was made.

$^{131}$I releases from the Omega Stack

Rep. No. 1181 includes memoranda that describe sampling performed to quantify releases of $^{131}$I from the Omega stack in 1965 and the measurement of the iodine collection efficiency for various sampling cartridges. The stack sampling was performed using a parallel arrangement of two samplers. Each of the two samplers consisted of two charcoal cartridges in series. The $^{131}$I collection efficiency of the cartridges during the various sampling runs is reported to have averaged from 95% to 98%. The samples were assayed via counting the 0.36-keV photopeak. Decay correction was applied only to account for the time between the end of the sample collection period and counting. Thus, the data are biased low, with the magnitude of this error depending on the sample duration. For most of the samples, this error will be small (less than 10%) since the sampling durations were not long relative to the half-life of $^{131}$I.

The $^{131}$I sampling data cover a time period from July 29, 1965 to October 4, 1965. Sampling was performed on 30 different days during this period. Six of the samples were collected over a three-day period (approximately 72 hours) with the remainder being collected over roughly a 24-hour period. The actual sampling durations and flow rates are given for each sample.

Table 10 shows a spreadsheet created using the $^{131}$I sampling data described above. The data were converted to μCi/cc to facilitate comparison with radiation protection guidelines. The average concentration for each sampling period is given, along with the average and standard deviation over all of the samples. The maximum concentration observed during the sampling period (on September 16, 1965) has been highlighted. No explanation is given in the memo report documenting the sampling data for why the concentration on this day was so much higher than for the other days.

One perspective that can be applied to the data in Table 10 is to compare the average stack concentration to the current 10 CFR 20 Appendix B limit for airborne effluent releases of $^{131}$I for NRC licensees. The 10CFR20 Appendix B limit for continuous release of $^{131}$I for a calendar year is $2 \times 10^{-10}$ μCi/cc. Thus, the average $^{131}$I concentration over the 30 days sampled in 1965 exceeds this value by nearly two orders of magnitude, and no single sampling result showed an average concentration less than this value.

Exposure to occupants of the "old trailer court" from Omega Site releases

Rep. No. 510 includes memos from Bemis to Shipman dated May 20, 1950 and July 11, 1950 that document the source of elevated gamma radiation levels observed at the edge of Omega canyon near the Trailer Village. It is stated that levels of 0.6 mR/hr were measured on several occasions. Surveys made at Omega site determined the source of this elevated gamma flux to be the condensate trap that filtered non-gaseous constituents out of the Water Boiler offgas before it enter the Omega stack. Exposure rate measurements made at head height at about 4 feet from the pit read more than 14 R/hr at the northeast corner and 2.2 R/hr at the southeast corner. It is implied that the Water Boiler was operating at full power when these measurements were made. Measurements also showed that the dose rate at the Trailer Village dropped by 50% immediately after the Water Boiler was shut down, showing that the pit still remained a source of exposure when the reactor was not operating.

Given the elevated readings found at the edge of Omega Canyon at the Trailer Village, it was proposed that a concrete building be built around the condensate trap to shield it. The combination of this proposed shielding structure and additional lead placed over the line at the trap was projected to reduce the maximum dose rate at the Trailer Village to around 1% of what it was previously. This 1% value is characterized in the July 11 memo as "about normal background."

**Table 10: $^{131}$I sampling results for the Omega Stack from 1965**

| Date | Duration (hours) | Flow Rate (cfm) | Vol. Sampled ($ft^3$) | I-131 Activity Sampler A (dpm) | I-131 Activity Sampler B (dpm) | I-131 Activity Average (µCi) | Average Concentration* (µCi/cc) |
|---|---|---|---|---|---|---|---|
| 7/29/65 | 22.3 | 1.0 | 1338.0 | 700617 | 729329 | 3.2E-01 | 8.9E-09 |
| 7/30/65 | 71.5 | 1.0 | 4290.0 | 964325 | 1062397 | 4.6E-01 | 4.0E-09 |
| 8/2/65 | 24.0 | 1.0 | 1440.0 | 470974 | 293223 | 1.7E-01 | 4.4E-09 |
| 8/3/65 | 23.5 | 1.0 | 1410.0 | 578063 | 380947 | 2.2E-01 | 5.7E-09 |
| 8/4/65 | 23.7 | 0.5 | 711.0 | 284514 | 187875 | 1.1E-01 | 5.6E-09 |
| 8/5/65 | 24.0 | 0.5 | 720.0 | 215021 | 133482 | 7.8E-02 | 4.1E-09 |
| 8/6/65 | 71.5 | 0.5 | 2145.0 | 494111 | 318514 | 1.8E-01 | 3.2E-09 |
| 8/9/65 | 23.8 | 0.5 | 714.0 | 218032 | 126051 | 7.7E-02 | 4.0E-09 |
| 8/10/65 | 24.0 | 0.5 | 720.0 | 243818 | 147114 | 8.8E-02 | 4.5E-09 |
| 8/11/65 | 23.3 | 1.5 | 2097.0 | 598642 | 445416 | 2.4E-01 | 4.2E-09 |
| 8/12/65 | 23.8 | 1.5 | 2142.0 | 392023 | 324066 | 1.6E-01 | 2.8E-09 |
| 8/13/65 | 71.4 | 1.5 | 6426.0 | 1187706 | 925312 | 4.8E-01 | 2.8E-09 |
| 8/17/65 | 23.8 | 1.5 | 2142.0 | 237138 | 220740 | 1.0E-01 | 1.8E-09 |
| 8/18/65 | 23.4 | 1.5 | 2106.0 | 181994 | 210043 | 8.8E-02 | 1.6E-09 |
| 8/19/65 | 23.9 | 1.5 | 2151.0 | 252037 | 223774 | 1.1E-01 | 1.9E-09 |
| 9/14/65 | 21.2 | 1.0 | 1272.0 | 812913 | 777548 | 3.6E-01 | 1.0E-08 |
| 9/15/65 | 23.5 | 1.0 | 1410.0 | 4528545 | 4126953 | 1.9E+00 | 5.1E-08 |
| ~~9/16/65~~ | ~~24.3~~ | ~~1.0~~ | ~~1456.0~~ | ~~10332164~~ | ~~10123331~~ | ~~4.7E+00~~ | ~~1.2E-07~~ |
| 9/17/65 | 69.6 | 1.0 | 4176.0 | 1750400 | 1668654 | 7.7E-01 | 6.9E-09 |
| 9/20/65 | 23.5 | 1.0 | 1410.0 | 719351 | 690034 | 3.2E-01 | 8.4E-09 |
| 9/21/65 | 22.5 | 1.5 | 2025.0 | 1253921 | 1267426 | 5.7E-01 | 1.0E-08 |
| 9/22/65 | 24.6 | 1.5 | 2214.0 | 1133133 | 1032930 | 4.9E-01 | 8.2E-09 |
| 9/23/65 | 22.8 | 1.5 | 2052.0 | 622613 | 664541 | 2.9E-01 | 5.3E-09 |
| 9/24/65 | 71.9 | 1.5 | 6471.0 | 1280271 | 1200319 | 5.6E-01 | 3.2E-09 |
| 9/27/65 | 23.7 | 1.5 | 2133.0 | 353028 | 354947 | 1.6E-01 | 2.8E-09 |
| 9/28/65 | 24.3 | 0.5 | 729.0 | 213553 | 176814 | 8.8E-02 | 4.5E-09 |
| 9/29/65 | 23.9 | 0.5 | 717.0 | 161961 | 117219 | 6.3E-02 | 3.3E-09 |
| 9/30/65 | 24.5 | 0.5 | 735.0 | 105608 | 48035 | 3.5E-02 | 1.8E-09 |
| 10/1/65 | 71.5 | 0.5 | 2145.0 | 224817 | 189888 | 9.3E-02 | 1.6E-09 |
| 10/4/65 | 23.5 | 0.5 | 705.0 | 219743 | 185989 | 9.1E-02 | 4.8E-09 |
| | | | | | | **Average =** | 1.0E-08 |
| | | | | | | **Std. Dev. =** | 2.2E-08 |
| | | | | | | **Pct. Std. Dev. =** | 224% |

*includes correction for 95% collection efficiency

The H-division progress report for January 20, 1951 to February 20, 1951 (Rep. No 2201) states that work had begun on an experimental dose rate (Rep) recorder to be installed in the trailer area opposite the Omega stack. The intent was to have a recorder in the H-1 Group Office that could record dose rates in the trailer area and be set to alarm if the dose rate exceeded some level. However, a review of the subsequent monthly progress reports for H-division for 1951 did not find any additional mention of this instrument, though some of these reports are incomplete. There is also no mention of the monitor ever having been completed or installed in the "new equipment" section of the H-division annual report for 1951 (Rep. No. 2287).

In July of 1963, a memo report (Rep. No. 2432) was published by Dale Hankins that documented an assessment of radioactive gas concentrations that might be present in the "old trailer court area" from the Omega stack effluent. It is presumed that "old trailer court" in this case refers to the area off of DP Road and not the Royal Crest trailer court off of East Jemez Road. The report used the information from LAMS-2937 (discussed above) as a source term and combined it with average meteorological observations to predict the average concentration a resident of the trailer court would

be exposed to. Concentrations were expressed in terms of multiples of the non-occupational Radiation Concentration Guide (RCG) of that era for whole body immersion.

Effluent concentrations at the old trailer court area were estimated based on annual average data for wind speed and direction provided by group H-6. This same group also provided a dilution factor of 2000 for Omega Stack effluents for the trailer court area (500 meters away). This dilution factor was for a wind speed of 2 mph. Though not explicitly stated in the report, it appears dilution factors for other wind speeds were determined via linear extrapolation. Specifically, the dilution factor for a range of wind speeds (e.g., 6 mph to 10 mph) was determined by dividing the mean of the range into 2 mph. Thus, the dilution factor used for a range of 6 mph to 10 mph was $2 \div 8 = 0.25$ of the factor at 2 mph. The dilution factors used only accounted for wind speed, and not other meteorological conditions such as lapse rate or precipitation.

The dilution factor provided by H-6 for the 2 mph wind speed was used in conjunction with the source term data from LAMS-2937 to compute a compound RCG value based on the non-occupational RCG values of that era for the individual nuclides and a 168-hour week (continuous occupancy). Note that the assumption of continuous occupancy used is equivalent to assuming that the Water Boiler was operated 24 hours per day. The source term data used reflected operation for five days at 150 kWh per day. The nuclides considered and their respective RCGs are given in Table 11 below. The RCG values are based on exposure via immersion.

**Table 11: Radionuclide RCGs**

| Nuclide | RCG (µCi/cc) |
|---|---|
| Kr-85m | 1E-07 |
| Kr-87 | 2E-08 |
| Xe-133 | 3E-07 |
| Xe-135 | 1E-07 |
| Kr-88 | 1E-08 |
| Rb-88 | 3E-08 |
| A-41 | 4E-08 |

The compound RCG value determined for the operating conditions and nuclide mix described above was 60. This means the nuclide concentration in the trailer court area under conditions of 100% operation of the Water Boiler at 150 kWh per day for five days would be 60 times higher than the concentration guideline value <u>if</u> the wind blew constantly from the direction of the Omega Stack to the trailer court at 2 mph.

The compound RCG value of 60 for the trailer court area was corrected for actual annual average wind conditions by determining the fraction of time the wind blew from the south (the direction from the Omega Stack to the trailer court) and the fraction of time that the southerly wind blew at six speed intervals. The wind speed intervals covered a range from 3 mph to 30 mph. The meteorological data showed the wind blew from the south 19.5% of the time. The wind speed profile for southerly winds are given in Table 12 below:

**Table 12: Wind Speed Frequencies for the Omega Site**

| Wind Speed Range (mph) | Percent of time (for southerly winds) |
|---|---|
| 3 to 5 | 20.6% |
| 6 to 10 | 47.9% |
| 11 to 15 | 21.6% |
| 16 to 20 | 8.4% |
| 21 to 25 | 1.0% |
| 26 to 30 | 0.5% |

The wind direction and speed profile data described above are for 9:00 pm. It is presumed 9:00 pm was used to account for the effect of delay in the Water Boiler vent line, though this is not discussed in the report.

The annual average wind velocity and extrapolated dilution factor data used in conjunction with the compound RCG value of 60 for the trailer court area under constant wind conditions give a corrected compound RCG of 3.2. This means that a full-time occupant (at 168 hours per week) would be subjected to an immersion dose that was 3.2 times higher than the guideline value for that era if the Water Boiler ran constantly at 150 kWh per day. The report concludes that since the Water Boiler in reality was only operated for roughly 8 hours per day, a full-time occupant would have received a dose essentially equal to the guideline value. However, it is also pointed out that there is significant uncertainty in that estimation from the number of assumptions required and the uncertainty associated with the variables used.

Omega Site Unmonitored releases, fugitive emissions, etc.

A persistent source of air contamination at the Water Boiler facility was finally identified during 1951. The source was determined to be U-235 from an old spill that had seeped into the "interstices of the reactor," presumably meaning the reflector. The only means of addressing the problem was to institute additional ventilation (Rep. No. 2287).

In September of 1953, it was found that the bismuth blocks used in the north thermal column of the Water Boiler were binding, making them difficult to remove. The binding of the blocks resulted in small amounts of the bismuth being eroded away each time a block was installed or removed. This eroded material also contained polonium created through neutron activation of the bismuth, and thus resulted in contamination of the floor. The problem prompted a decision to remove the offending blocks and either dispose of them or file them into shape. Despite precautions taken to isolate this operation and inhibit the spread of contamination, contaminated dust was still "either tracked or blown to other parts of the building." The report states that activity on the floor was reduced to 200 cpm after several days of scrubbing (Rep. No. 2335).

Rep. No. 2336 reports that "an accident at the Omega Water Boiler on Aug. 3 [1953] caused a temporary rise in the background to 100 R/hr in the Reactor Room." No details are given on what specifically occurred.

Rep. No 2411 reports that on July 24, 1957, 120 cc of acid was added to the Water Boiler fuel solution. During this action fission product material was inadvertently drawn into an evacuated line and deposited on the top of the reactor. Exposure rates as high as 20 R/hr were measured on the floor surface.

Between January 20, 1958 and February 20, 1958, electricians cut in a power line at Omega Site causing a power failure. The loss of normal ventilation resulted in the area having to be evacuated due to high airborne concentrations of what was reported to be $^{137}Cs$. It was estimated that the $^{137}Cs$ concentration was at least 37 times tolerance, though no basis is given for this value. No air sampling was performed given the urgent need to evacuate the area (Rep. No 2416). This incident was followed by a rash of similar incidents, with power failures occurring on May 27, 1958 (at 2:52 pm); May 29, 1958 (at 4:00 pm); on June 6, 1958 (at 9:58 am); and on June 9, 1958 (at 9:30 am). All of these incidents required the area to be evacuated (Rep. No. 2420). This report also states that the source of these failures was finally corrected.

Offsite impacts associated with operation of the OWR

Following its initial criticality on June 29, 1956, all of the fuel elements were removed from the OWR on July 17 and checked for leakage (via smear counting). No leakage was indicated by any of the elements. Only July 19, the cooling water was discharged into the canyon after it was sampled and no activity found (Rep. No. 2387).

Gaseous activity in the OWR coolant (resulting from diffusion of noble gases out of the fuel elements) collected in the air space above the coolant in the surge tank. This activity was normally vented to the atmosphere at a rate of 0.2 $ft^3$/hr (LA-3116). Venting of gases from the surge tank could be switched to the Omega stack if high activity was suspected or observed. The approximate noble gas concentrations in the atmospheric effluent from the surge tank (circa. 1964) were (LA-3116):

$^{133}Xe$: $1.3 \times 10^{-2}$ μCi/cc
$^{135}Xe$: $5.4 \times 10^{-4}$ μCi/cc
$^{85}Kr$: $4.6 \times 10^{-4}$ μCi/cc
$^{41}Ar$: $8.6 \times 10^{-2}$ μCi/cc

The OWR reactor room, which was a routine work area, was exhausted via three roof exhaust fans. Rep. No. 645 reports the combined flow of these fans at an estimated 360 cfm in 1973. The exhaust from these fans contained small amounts of $^{41}Ar$. The OWR facility also had HEPA-filtered chemical hoods that exhausted to the environment.

$^{41}Ar$ releases from the OWR

$^{41}Ar$ releases from the Omega Stack (as reported by LANL) are summarized in Table 13 for the years 1967 through 1992. 1992 was the last year of operation for the OWR, as it was permanently shut down in December of that year.

It is unknown at present if the relatively large amount of $^{41}Ar$ released in 1967 and 1968 are indicative of releases for previous years. 1967 was the year in which the OWR's maximum operating power level was increased to 8 MW, though this may be coincidental. As a basis for comparison for the Ar-41 concentration data (where given), the current airborne effluent concentration limit for $^{41}Ar$ from 10 CFR 20 Appendix B is $1 \times 10^{-8}$ μCi/cc.

**Table 13: $^{41}$Ar releases from the Omega Stack**

| Year | Reported Release (Ci) | Reported Average Concentration (µCi/cc) | Reference |
|---|---|---|---|
| 1967 | 15546 | not given | Rep. No. 1811 |
| 1968 | 6482 | not given | Rep. No. 1811 |
| 1969 | 1814 | not given | Rep. No. 1806 |
| 1970 | 1300 | not given | Rep. No. 1811 |
| 1971 | 1600 | not given | Rep. No. 1811 |
| 1972 | 640 | not given | Rep. No. 1811 |
| 1973 | 273 | $2.1 \times 10^{-5}$ | Rep. No. 2099 |
| 1974 | 312 | $2.6 \times 10^{-5}$ | Rep. No. 2102 |
| 1975 | 237 | $1.823 \times 10^{-5}$ | H-1-77-55 |
| 1976 | 339.2 | $2.560 \times 10^{-5}$ | H-1-78-61 |
| 1977 | 314.7 | $2.421 \times 10^{-5}$ | CY 78 airborne release summary |
| 1978 | 239.2 | $1.840 \times 10^{-5}$ | H-1-80 |
| 1979 | 350.8 | $2.698 \times 10^{-5}$ | H-1-81 |
| 1980 | 512.7 | $3.944 \times 10^{-5}$ | H-1-RE-21 |
| 1981 | 300.7 | $2.313 \times 10^{-5}$ | H-1-RE-21 |
| 1982 | 342 | $2.59 \times 10^{-5}$ | HSE-1-RE-20 |
| 1983 | 418 | $3.21 \times 10^{-5}$ | HSE-1-RE-30 |
| 1984 | 335 | $2.57 \times 10^{-5}$ | HSE-1-FG-7 |
| 1985 | 390 | $2.97 \times 10^{-5}$ | HSE-1-FG-8 |
| 1986 | 276 | $2.10 \times 10^{-5}$ | HSE-1-89-63 |
| 1987 | 232 | $1.88 \times 10^{-5}$ | HSE-1-89-63 |
| 1988 | 264 | $2.46 \times 10^{-5}$ | HSE-1-90-248 |
| 1989 | 223 | $1.97 \times 10^{-5}$ | CY 1990 air emissions annual report |
| 1990 | 163 | $2.16 \times 10^{-5}$ | CY 1990 air emissions annual report |
| 1991 | 203 | not given | CY 1991 air emissions annual report |
| 1992 | 140 | not given | CY 1992 air emissions annual report |

Contemporary practice was to compute the amount of Ar-41 released from the Omega Stack on a 24-hour basis by multiplying the integral power for the OWR for that day (in MWh) by a conversion factor (in Ci/MWh). In 1990, this factor was increased twice (Rep. No. 523). In April, it was changed from 0.012 Ci/MWh to 0.015 Ci/MWh; then in July of the same year it was changed from 0.015 Ci/MWh to 0.018 MWh. The 0.018 Ci/MWh value was then used up until the OWR was permanently shut down in December of 1992. It is unknown at present how long the value of 0.012 Ci/MWh was used until it was increased in 1990, or if a different method(s) of determining $^{41}$Ar releases was ever used.

## 4.4 Reconstruction of Reported Effluents from TA-21

Table 14 shows for each month of each year from 1943 to 1995 the monitoring data that exists for TA-21. The entries in the table identify whether the effluent data format is daily (D), weekly (W), monthly (M), quarterly (Q), or yearly (Y). The colors are meant to signify where the information is located: green implies that the project team has the documents for the indicated time period; yellow implies that the team has not received documents for the indicated time period, but a document summary form (DSF) is in the database; red implies that no information has been identified for the indicated time period. Table 14 also includes a column identifying whether or not stack flow rate information is available.

Table 15 shows what types of effluent data exist in Table 14: 'Xn' indicates that records provide effluent concentration in various units; 'dpm' indicates that the effluent data are presented in activity units of dpm; 'Ci' indicates that the effluent data are presented in activity units of curies.

Information currently lacking from the records in the database that is needed to reconstruct releases includes:

1) Details on the stacks at DP site such as hours of operation, dimensions, and locations. Some information on stack location has been found.
2) Information on stack flow rates.
3) Information on the mechanisms and methods used for stack sampling.
4) Information on the procedures for measuring and recording of stack samples.
5) Information on the instruments used to count the stack samples.

**Table 14: TA-21 Effluent Monitoring Data in the Project Database**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Stack Flow Rates |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1943 | | | | | | | | | | | | | |
| 1944 | | | | | | | | | | | | | |
| 1945 | | | | D | D | D | D | D | D | D | D | D | |
| 1946 | MC | M | M | M | M | M | MC | MC | MC | MC | MC | MC | |
| 1947 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1948 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1949 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1950 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1951 | D | D | D | D | D | D | D | D | D | D | D | D | |
| 1952 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1953 | C | C | C | C | C | | | | | | | | |
| 1954 | | | | | | | | | | | | | |
| 1955 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1956 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1957 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1958 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1959 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1960 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1961 | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | MQY | |
| 1962 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1963 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1964 | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | |
| 1965 | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | |
| 1966 | W | W | W | W | W | W | W | W | W | W | W | W | |
| 1967 | MWC | MWC | MWC | MWC | MWC | MWC | MWC | MWC | MWC | MWC | MWC | MWC | |
| 1968 | C | C | C | C | C | C | C | C | C | C | C | C | |
| 1969 | C | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | WM | |
| 1970 | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | DMMQ | |
| 1971 | WMC | WMC | WMC | WMC | WMC | WMC | WMC | WMC | WMC | WMC | WMC | WMC | |
| 1972 | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | |
| 1973 | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | MW | |
| 1974 | WM | WM | WM | WM | WM | WM | WM | WM | M | M | M | M | |
| 1975 | | | | | | | | | | | | | Jan.-U |
| 1976 | | | | | | | | | | | | | |
| 1977 | | | | | | | | | | | | | |
| 1978 | C | C | C | C | C | C | C | C | C | | | | |
| 1979 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | |
| 1980 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | |
| 1981 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | |
| 1982 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | |
| 1983 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Yag bwdis |
| 1984 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Yag bwdis |
| 1985 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Yag bwdis |
| 1986 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Yag bwdis |
| 1987 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Yag bwdis |
| 1988 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Yag bwdis |
| 1989 | | | | | | | | | | | | | Yag bwdis |
| 1990 | | | | | | | | | | | | | Yag bwdis |
| 1991 | | | | | | | | | | | | | Yag bwdis |
| 1992 | | | | | | | | | | | | | |
| 1993 | | | | | | | | | | | | | |
| 1994 | | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | | |

**Table 15: Types of TA-21 Effluent Data Corresponding to the Entries in Table 14**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1943 | | | | | | | | | | | | |
| 1944 | | | | | | | | | | | | |
| 1945 | | | | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1946 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1947 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1948 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1949 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1950 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1951 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1952 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1953 | Xn | Xn | Xn | Xn | Xn | | | | | | | |
| 1954 | | | | | | | | | | | | |
| 1955 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1956 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1957 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1958 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1959 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1960 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1961 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1962 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1963 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1964 | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm |
| 1965 | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm | dpm |
| 1966 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1967 | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn |
| 1968 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1969 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1970 | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn | dpm, Xn |
| 1971 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1972 | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm |
| 1973 | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm | Xn, dpm |
| 1974 | dpm,(Xn, Ci) | dpm,(Xn, Ci) | dpm,(Xn, Ci) | dpm,(Xn, Ci) | dpm,(Xn, Ci) | dpm,(Xn, Ci) | dpm,(Xn, Ci) | dpm,(Xn, Ci) | Xn,Ci | Xn,Ci | Xn,Ci | Xn,Ci |
| 1975 | | | | | | | | | | | | |
| 1976 | | | | | | | | | | | | |
| 1977 | | | | | | | | | | | | |
| 1978 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | | | |
| 1979 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1980 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1981 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1982 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1983 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1984 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1985 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1986 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1987 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1988 | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn | Xn |
| 1989 | | | | | | | | | | | | |
| 1990 | | | | | | | | | | | | |
| 1991 | | | | | | | | | | | | |
| 1992 | | | | | | | | | | | | |
| 1993 | | | | | | | | | | | | |
| 1994 | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | |

**KEY:** 'Xn' indicates that records provide effluent concentration in various units; 'dpm' indicates that the effluent data are presented in activity units of dpm; 'Ci' indicates that the effluent data are presented in activity units of curies.

## 4.5 Estimation of D-Building Releases

The original plutonium processing facility at Los Alamos was located in Building D at TA-1, at a location now occupied by the Los Alamos Inn. It was in this building that the first plutonium metal samples (also called buttons) were formed from the pile (reactor) generated plutonium that initially came from the Clinton Laboratories at Oak Ridge and later, in much larger amounts, from the Hanford site. It was also in this building that the Chemistry and Metallurgy (CM) Division personnel performed their work to determine the chemical and metallurgical properties of plutonium. These properties had to be determined before any plutonium metal could be fabricated into weapon components.

Initially there were certain requirements for the concentration of impurities in the plutonium that had to be met if the metal were to be used successfully. These requirements were designed under the assumption that the metal would be used in a weapon similar to that being designed for uranium metal, the gun-type weapon. It was recognized that achieving the impurity limits was going to be exceptionally difficult.

Building D was built in response to these issues with purity. It was a building where the needed chemical and metallurgical studies of the metal could be conducted with minimal contamination. Any contamination introduced from the working environment only worsened the impurity problem, so it was necessary to work in a clean-as-possible environment and in one that particularly avoided airborne dust. Building D was built with state-of-the-art dust-free air conditioning technology.

As a plutonium processing facility, one would naturally expect the airborne effluent from the building to contain plutonium. To date, CDC analysts have found no airborne effluent monitoring data for Building D, but they have found the monthly group reports from CM-12 (later CMR-12) that include room air monitoring data (Rep. No. 139).

An airborne effluent estimation method has been devised by the project team to make use of the room air monitoring data that have been found. This method is described in detail in Appendix B. This method was used to estimate the plutonium releases from Building D for the years prior to 1948. In the previous airborne plutonium release estimate, the years prior to 1948 were missing from the analysis due to a lack of data for these years. The two places contributing to airborne plutonium releases for these years were Building D and DP Site. The contribution from DP Site is studied separately.

The D-Building release estimation methodology begins with the room air concentration measurements that were found in the CM-12 (later CMR-12) monthly reports (Rep. No. 139). The method is summarized below in equation form, and the individual terms are described. The first equation gives the concentration of the effluent in microcuries per liter; the second gives the flow rate, and the third yields the total time per month. When multiplied together in the fourth equation, the terms yield the estimated quantities of radionuclide released, in microcuries per month.

## 4.6 Availability of Waterborne Radionuclide Effluent Data

Waterborne radionuclide release estimates generated by LANL personnel have been located in several documents that have been reviewed by the project team. The most useful information identified to date comes from the following two sources:

- Source Number 1: A memorandum concerning the LANL site nuclide inventory, liquid discharges, atmospheric releases, disposal by burial, and seepage pond disposal. This memo is part of a compilation of effluent-related correspondence and documentation found in a notebook at the ES&H records center, and covers releases up to 1972.

- Source Number 2: Repository Document Number 2001, which summarizes effluent discharges for the period 1943 – 1972 for several of LANL's Technical Areas.

We have assembled the data contained in the nuclide release memoranda in the first collection that was found at the ES&H center at TA-35, as well as some data from other documents. We have summarized the data in the following tables and plots. The sources described above do not provide a complete picture of the liquid releases, as there are some years missing from the data. In general, we have release information from 1945 to 1972. Note that this time period does not include the war effort years of 1943 to 1945. It is expected that release information for 1943 to 1948 would substantially increase the release amounts reported below. In Table 16, total releases up to 1972 for the Technical Areas are shown. This table was generated from the data in the second source. The data from the second source, which was used to generate the tables below, is to some extent inconsistent with the data from the first source, which are shown in Table 17. Both tables should cover the same time period.

**Table 16: Reported Total Waterborne Radionuclide Releases (Curies)**

| | Nuclide | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **Sr-89** | **Sr-90** | **H-3** | **Total Pu** | **Pu-239** | **Ba-La-140** | **Ac-227** | **Cs-137** |
| **DP Site** | 0.4 | 3.0 | 35.7 | 10.6 | 0.1 | 3.4E-02 | 2.5 | 1.2E-02 |
| **Ten Site** | 1.3 | 0.2 | | | | | | |
| **TA-50** | 0.4 | 0.3 | 6.0 | 3.4E-02 | 1.0E-03 | | | |
| **TA-45** | | | 42.0 | 2.7E-02 | | | | |
| **Acid Canyon** | 0.3 | 0.1 | 18.3 | 0.2 | | | | |
| **Total (Ci)** | 2.4 | 3.6 | 101.9 | 10.8 | 0.1 | 3.4E-02 | 2.5 | 1.2E-02 |

The exact isotopic composition of the "Total Pu" liquid release is not known. The first source does state, however, that the Laboratory did not discharge "any substantial quantities of Pu-238 until 1967. No routine analyses were made to differentiate between Pu-238 and Pu-239 until 1971. At this time about 80% of the plutonium activity was attributed to Pu-238. This percentage has continued to increase and Pu-238 now accounts for about 95% of the total plutonium activity." The first source is dated November 13, 1973.

The source documents listed above refer to releases of unidentified beta and alpha emitters in unknown quantities. These unknowns are not given in our tables. At other times, the amount of a particular nuclide released was unknown, which precluded its inclusion in this table. For some nuclides, the release amounts sometimes included estimated release totals. This is evident in Table 18, where constant annual release totals are seen over certain spans of years. The source documents clearly state when a value was an estimate. Finally, it should be noted that these activity totals are not decay corrected; the release amounts are sums of annual releases at the time of their release.

**Table 17: Waterborne Activity Released as Reported by the First Source**

| Nuclide | (Ci) |
|---|---|
| Pu-238 | 0.043 |
| Pu-239 | 0.21 |
| H-3 | 140 |
| Sr-90 | 0.65 |
| Sr-89 | 2.4 |

The TAs released their liquid effluent into specific canyons. For example, Ten Site (TA-35) released into Ten Site canyon, which is a tributary canyon to Mortandad canyon, TA-50 released into Mortandad canyon, and DP Site released into DP Canyon, which is a tributary to Los Alamos Canyon. Releases to Acid Canyon date from the war effort years.

**Table 18: Reported Annual Releases of Waterborne Radionuclides (Curies)**

| | Sr-89 | Sr-90 | H-3 | Total Pu | Pu-239 | Ba-La-140 | Ac-227 | Cs-137 |
|---|---|---|---|---|---|---|---|---|
| 1945 | 0.0205 | 0.1725 | 3 | 1.02 | 0.0035 | 0.002 | | |
| 1946 | 0.0205 | 0.1725 | 3 | 1.02 | 0.0035 | 0.002 | | |
| 1947 | 0.0205 | 0.1725 | 3 | 1.02 | 0.0035 | 0.002 | | |
| 1948 | 0.0205 | 0.1725 | 3 | 1.22 | 0.0035 | 0.002 | | |
| 1949 | 0.0205 | 0.1725 | 3 | 1.22 | 0.0035 | 0.002 | | |
| 1950 | 0.0205 | 0.1725 | 3 | 2.02 | 0.0035 | 0.002 | | |
| 1951 | 0.0205 | 0.1725 | 3.25 | 2.41 | 0.0035 | 0.002 | | |
| 1952 | 0.0205 | 0.1725 | 5 | 0.80 | 0.0035 | 0.002 | | |
| 1953 | 0.0205 | 0.1725 | 5 | 0.00 | 0.0035 | 0.002 | 2.5 | |
| 1954 | 0.0205 | 0.1725 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1955 | 0.0205 | 0.1725 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1956 | 0.9555 | 0.3375 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1957 | 0.2335 | 0.2095 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1958 | 0.1225 | 0.1833 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1959 | 0.0465 | 0.1765 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1960 | 0.0545 | 0.1785 | 5 | 0.00 | 0.0035 | 0.002 | | |
| 1961 | 0.0295 | 0.1735 | 5 | 0.01 | 0.0035 | 0.002 | | |
| 1962 | 0.009 | 0.001 | 5 | 0.01 | | | | |
| 1963 | 1.49E-01 | 3.98E-02 | 5 | 0.01 | | | | |
| 1964 | 6.07E-02 | 8.87E-02 | 5 | 0.00 | | | | |
| 1965 | 4.23E-02 | 6.18E-02 | 2 | 0.00 | | | | |
| 1966 | 2.44E-02 | 3.56E-02 | 2 | 0.00 | | | | |
| 1967 | 5.35E-02 | 1.34E-02 | 2 | 0.01 | | | | 0.012 |
| 1968 | 3.26E-02 | 5.06E-02 | 0 | 0.00 | | | | |
| 1969 | 5.46E-02 | 1.46E-02 | 0 | 0.01 | | | | |
| 1970 | 1.54E-02 | 2.24E-02 | 0 | 0.01 | | | | |
| 1971 | 1.30E-02 | 3.22E-02 | 0 | 0.01 | | | | |
| 1972 | 4.17E-03 | 6.51E-03 | 9.62E+00 | 0.00 | 2.16E-03 | | | |
| Total | 2.1 | 3.5 | 101.9 | 10.8 | 0.1 | 0.0 | | |

# 5. AVAILABILITY OF ENVIRONMENTAL MONITORING AND RESEARCH DATA

This section describes the project team's current understanding of environmental monitoring and research data that may be useful for any future dose reconstruction studies. The data reviewed thus far represents samples collected in both on-site and off-site areas potentially affected by past contaminant releases from Los Alamos National Laboratory operations. These data are being reviewed, and other data of this type will be reviewed to determine the extent of information that is available and to establish how useful this information would be for future investigations aimed at quantifying historical exposures and health risks to off-site populations. This section of the report will be updated as more data is reviewed during the LAHDRA project. Tables of sample environmental data sets are presented in Appendix C.

## 5.1 Areas of Investigation

This investigation of available environmental monitoring and research data focuses on the primary environmental media likely to have been associated with Laboratory releases and contaminant exposures to off-site populations. The following section describes the geographical areas of interest during the investigation. These areas were selected for investigation based on:

- The LAHDRA project team knowledge of the key release sources at the Laboratory,
- Previous environmental studies of on-site and off-site areas,
- Surface waters that have been impacted by past LANL emissions,
- Reported areas of contaminant accumulation in surface water, sediment, and surface and subsurface soils,
- Annual airborne releases and effects from local and regional wind patterns and local and regional topography, and
- Historical environmental surveillance and monitoring and our preliminary review of environmental data availability.

Environmental monitoring within the laboratory boundary and surrounding areas began shortly after the start of Laboratory operations in 1943. Most of the early monitoring involved collection of non-routine air, water, soil, and sediment samples for radioactive analyses. The early environmental monitoring program was used to determine the spread of radioactive contamination to surrounding land areas and to estimate potential radiation exposures that might be occurring as a result of laboratory emissions. The monitoring program grew in size and scope as activities at the laboratory expanded. Increased monitoring over the years meant the collection of a larger number of routine samples for all types of media (air, water, soil) and for a growing list of contaminants. The frequencies for which samples were collected also increased over the years and with the advent of new environmental protection and compliance laws of the early 1970s, LASL saw the need to further increase their monitoring of the environmental conditions both on-site and off-site and enhance the format with which they reported measurement results. The need to do more monitoring was also brought to the LASL'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 later on beginning in the late 1960s and 1970s some limited sampling was performed for lead, mercury, chromium, and beryllium. A review of early LASL's environmental monitoring of the surrounding areas (e.g., canyons) 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 impacts from LASL (Parker, 1974).

Environmental monitoring of the laboratory and surrounding areas has been conducted primarily by the University of California-Los Alamos National Laboratory, the United States Atomic Energy Agency and its successors, U.S. Geological Services, and in more recent years the State of New Mexico. From 1955 to 1970 the U.S.G.S. performed radiochemical and metal analyses of samples collected from supply wells, the Rio Grande River, local surface streams, and test monitoring wells.

This investigation is focusing on the availability of sampling and monitoring data for all media of interest including air (air samples and direct radiation), surface water, ground water, soil, sediments in surface water areas of interest, food sources, and biota in the surrounding mesa and canyon areas that have been impacted by historical LANL releases.

The areas of concern for the investigation of environmental data include:

- Los Alamos community
- Espanola community
- White Rock community
- Surrounding Native American Reservations
- Los Alamos Canyon
- DP Canyon
- Pueblo Canyon
- Acid Canyon
- Rio Grande River
- Mortandad Canyon
- Bayo Canyon
- Pajarito Canyon
- Sandia Canyon
- Guaje Canyon
- Area reservoirs

## 5.2 Conditions at LANL and Surrounding Areas

The laboratory site and adjacent communities are situated on the Pajarito Plateau that consists of a series of mesas separated by deep canyons cut by intermittent streams that trend south-eastward from an altitude of about 2400 meters at the Jemez Mountains to about 1800 meters at the eastern margin where they terminate above the Rio Grande Valley. The canyons and mesas areas are underlain by the Bandelier Tuff composed of ashfall and ashflow pumice and rhyolite tuff that form the surface of Pajarito Plateau. The volcanic ash was deposited in the Jemez Mountains to the west 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, but the amount is insufficient to maintain flow across the laboratory area before it is depleted by evaporation, transpiration, and infiltration. Runoff from heavy thunderstorms and heavy snowmelts reaches the Rio Grande several times a year. Effluents from the laboratory provided sufficient flow to maintain surface flow in the canyons up to 1.5 kilometers (LASL, 1980).

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 meters and is quick permeable in contrast to the underlying volcanic tuff and sediments. This results in a shallow alluvial groundwater that moves down gradient in

the alluvium and becomes depleted as it moves into the underlying volcanics. In lower Los Alamos and Pueblo Canyons, a small local body of perched water id 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 meters along the western margin of the Plateau to about 180 meters 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).

## 5.3 Availability of Environmental Data

Much of the environmental monitoring results reported for years prior to 1970 and identified thus far by the project team are published in letter-type reports, and vary widely in content and detail. In some cases, only a portion of a report is available to date for review by the project team. Copies of full reports are preferred and are continually sought by the project team. While environmental monitoring during the early years generated a smaller amount of data when compared to last thirty years of monitoring, many of pre-1970 reports may not be available or will require more research to locate. The project team is focusing their efforts on gathering additional data for these early years and is in the process of organizing it into a format that can be useful in supporting prioritization of releases.

## 5.4 Summary of the Content of Annual Environmental Surveillance Reports

Beginning in 1970, as environmental monitoring increased beyond the sampling that was performed during prior years, Los Alamos Scientific Laboratory began to publish annual reports for environmental monitoring results based on sampling and analyses conducted by laboratory 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.

During this period, environmental samples were collected and analyzed by the Laboratory's Environmental Services Group. Large amounts of environmental samples were collected and analyzed for both radionuclides and chemicals. Table 19 presents a summary of chemical and radionuclide monitoring data that are available in the annual environmental surveillance reports. Monitoring data summarized in Table 19 represents chemical and radionuclide concentrations in various environmental media such as $^{239}$Pu in air.

To date, environmental surveillance reports have been located for July - December 1970, January - June 1971, July - December 1971, and every calendar year from 1972 to 2000. Specific reports are identified in the reference list that follows this section.

## Table 19: Data Availabilty - LANL Annual Environmental Surveillance Reports (1971 - 1999)



| 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 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 52 | 52 | 52 | 52 | 52 |
| 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 | • | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |

[a] nature and extent of windrose, temperature, and percipitation data varies for each reported year

## Table 19: Data Availabilty - LANL Annual Environmental Surveillance Reports (1971 - 1999)



| 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 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 166 | 166 | 166 | 95 | 97 |
| Radiation Dose Ass. | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| Special Studies | • | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| Honey bees- Rad. | • | • | • | | | | | | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| Unplanned releases | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |

[a] nature and extent of windrose, temperature, and percipitation data varies for each reported year

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, 1978). Additional descriptions of the types of monitoring data contained in the annual reports are presented below.

Appendix C contains examples of the data that the project team is currently reviewing to determine their relative usefulness for conducting screening calculations, source term validation studies, and dose assessments. These tables will be revised as more monitoring data is identified and reviewed by the project team.

Presented below is a list of the LASL/LANL Annual Environmental Surveillance reports reviewed as the basis for Table 19, and that are being further evaluated and drawn upon to assemble potentially useful information that could support dose assessment studies.

## 5.5 Early Environmental Monitoring Data Availability

Early environmental monitoring in areas of interest consist primarily of routine radiochemical analyses and some limited chemical and/or metal analyses. Below is a selection of some of these data that are available for evaluation and possible use in any future dose reconstruction studies.

Los Alamos and Pueblo Canyons

During the early period from 1943 to roughly 1950, waste water from the Technical Area were released to Los Alamos Creek (Los Alamos Canyon) to the southwest of the area and to Pueblo Creek (Pueblo Canyon) to the north of the area. Liquid effluents primarily contained plutonium and polonium. Plutonium was largely released from laundry facility located in the Technical Area, D Building, Sigma Building, U Building, V Building, M Building in the Technical Area, and DP West. Polonium was primarily released from H Building in the Technical Area and DP East. Employees from LASL's CMR-12 Group collected water samples from surface waters found in the canyons and analyzed them for plutonium, polonium, tritium, and gross alpha and gross beta radioactivity. The monitoring was designed to determine the environmental concentrations between the Technical Area at the Laboratory and the Rio Grande River (Tribby, 1945).

The Los Alamos and Pueblo Canyons join about two miles east of the Technical Area One and drops about 2,000 feet to the Rio Grande River. Starting in 1943, one liquid discharge pipe serviced all chemical operations in Technical Area 1 (TA-1). This discharge pipe was used to drain all laboratory floors and sinks used in the chemical operations and released untreated effluents to Pueblo Canyon (Tribby, 1947). The original intent of releasing the liquid effluent in this manner was for natural dilution to reduce contaminant concentration as effluent waters flowed to the Rio Grande River. More information is being sought and reviewed by the project team to determine how long this liquid discharge point was in operation and what changes in the types and quantities of contaminants discharged occurred over its operating history.

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 two seepage pits systems. These pits were designed to hold the liquids for seepage to underlying soils and evaporation, but are reported to have clogged on occasion and resulted in release of waste liquids to Pueblo Canyon.

Monitoring of radioactive contamination within 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 LASL 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/liter. 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/gram. Polonium levels around TA-3 seepage pits were measured up to 3,000 dpm/gram. In 1947, Tribby reports that plutonium levels on canyon walls and canyon beds near discharge points were quite high and that concentration levels drop-off rapidly 100 feet and beyond release points.

TA-45 – From 1943 to mid-1953, the TA-45 facility only treated liquid waste from the Main Technical Area (TA-1). Beginning in the second half of 1953, wastes from TA-1 and TA-3 were treated at TA-45.

During the early years (1943 – 1960s) wastes from TA-1 and TA-3 were treated at the TA-45 Waste Treatment Facility and discharge to Pueblo Canyon. Early on Ferric sulfate and lime were added to incoming wastes to form a precipitate of ferric hydroxide which contained most of the plutonium which would in turn settle to the bottom of the waste storage tanks. Also during this period liquid wastes from DP West production area were treated at the DPW Area Waste treatment Plant and released to Los Alamos Canyon.

Bayo Canyon

From 1944 to 1961, Bayo Canyon was used as the site for high explosive tests involving radioactive lanthanum, strontium-90, and uranium. The experiments led to the spread of radioactive contamination in canyon. Radiochemistry operations in the canyon generated liquid radioactive wastes that were disposed of in subsurface pits and leaching fields (LASL, 1978). Bayo Canyon is located adjacent to Los Alamos town site and is bounded to the south by Kwage Mesa and to the north by Otowi Mesa. The explosive assemblies consisted mainly of uranium and lanthanum-140 with small amounts of strontium-90. The explosions dispersed uranium and source activity to the air and ground surface.

Mortandad Canyon

During this same period, wastes from TA-35 were treated at the Ten Site Waste Treatment Plant and discharged to Mortandad Canyon.

Pajarito Canyon, Rio Grande River, Sandia Canyon, and Area Reservoirs

Review in process.

## 5.6 Summary of 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 associated with the 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

Available surface water and sediment monitoring data collected in areas of concern described in the above section is presented below. Due to large volumes of data, not all of the available data have been analyzed and compiled for this draft report. As more information is reviewed, the project information database will more completely reflect the availability of environmental monitoring and research data.

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 and terminated at the Rio Grande River about 0.25 miles downstream of Otowi Bridge (Tribby, 1945; Tribby, 1947). The samples were the 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 counting laboratory for analyses.

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 et al., 1948; Schnap, 1950).

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 include: 1) Pueblo Canyon at Otowi Ruins, 2) Los Alamos canyon at bridge, 3) Los Alamos Canyon at Totavi, and 4) Bayo Canyon (Abrahams, 1958a; Abrahams, 1958b). Monthly samples were analyzed for gross alpha, plutonium, uranium, and gross beta. 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. One location in Bayo Canyon was sampled for gross alpha, plutonium, and uranium.

Study #4: Radioactivity in Rio Grande River (1957–1958)-- During 1957, the U.S. Geological Survey collected water samples from the Rio Grande River. Monthly samples were analyzed for gross alpha, plutonium, and uranium, and gross beta. Samples were collected at stations Embudo, Chama, Otowi, and Cochiti (Abrahams, 1958a; Abrahams, 1958b).

Study #5: Radioactivity, Chromate, and Zinc in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons (1969-1970)-- During 1969 and 1970, LASL (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 show 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 are reported:

- 27 pCi/g in lower Acid Canyon
- 4.6 pCi/g in Pueblo Canyon one mile below Acid Canyon
- 1.1 pCi/g in Pueblo Canyon two miles below Acid Canyon
- 1.1 pCi/g in Pueblo Canyon 0.1 mile above 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 millicuries (Hanson, 1973). Plutonium measured in surface water samples collected in Acid and Pueblo Canyons averaged 20 pCi/L during this period, compared to 1.5 and 0.22 pCi/L in Mortandad and Los Alamos Canyons, respectively.

Study #7: Radioactivity in Bayo Canyon (1977)-- During 1977, LASL collected surface water samples from Bayo Canyon. Radiochemical analysis of samples showed that residual $^{90}$Sr concentrations in soil averaged for the time period was 1.4 pCi/g (LASL, 1978b).

Historical Soil Monitoring Data

Available soil monitoring data collected in areas of concern described in the above section is presented below. Due to large volumes of data, not all of the available data has been analyzed and compiled for this draft report. As more information is reviewed, the project database containing environmental data will be updated in future version of this report.

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 et al., 1948).

Study #7: Radioactivity in Bayo Canyon (1973-1977)-- During 1977, LASL 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 (LASL, 1978b). 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

Available external radiation monitoring data collected in areas of concern described in the above section is presented below. Due to large volumes of data, not all of the available data has yet been analyzed and compiled.

Study #1: Direct Radiation Readings in Los Alamos Canyon (1947)-- Direct radiation measurements with a Geiger Mueller survey meter were collected throughout Los Alamos Canyon as some of the first reported measurements of this type. The discharge line, 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 radiation (Tribby, 1947).

Study #8: Radiation Levels in Mortandad Canyon (1952)-- In 1952, LASL scientist conducted a series of radiation surveys throughout Mortandad Canyon and concluded that subsequent rainfalls enhanced the migration of measurable radioactive contamination several miles downstream in the canyon (Aeby, 1952). Results are reported in units of mr/hour. The report provides a concentration and volume of radioactive material released to the canyon. Specific isotopes are not stated in the memo report.

Study #7: Radioactivity in Bayo Canyon (1973-1977)-- Direct radiation measurements throughout Bayo canyon were taken with ion chambers and germanium detectors (LASL, 1978b).

Historical Ambient Air Monitoring Data

Available ambient air monitoring data (including meteorological) collected in areas of concern described in the above section is presented below. Due to large volumes of data, not all of the available data has yet been analyzed and compiled for this draft report.

Study #9: LANL Meteorological Data (1956 to 1971)— Measured wind, temperature, pressure, humidity, and precipitation collected at various locations throughout the Los Alamos and surrounding areas are presented (LANL, 1976).

Study #10: Beta/Gamma Concentrations at LANL (1961)-- Airborne radioactive particulate samples collected on filter paper are reported for an air sampler located on the roof of the Administration Building SM-43. Air samples were collected every 24 hours and 72 hours over weekends (LASL, 1961). Report contains sampling results for the first quarter, 1961.

Historical Groundwater/Water Supplies Monitoring Data

Available groundwater monitoring data collected in areas of concern described in the above section is presented below. Due to large volumes of data, not all of the available data has yet been analyzed and compiled for this draft report.

Study #4: Radioactivity in Los Alamos, Pueblo, and Guaje Canyons (1957-1958)-- During 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, 1958a; Abrahams, 1958b).

Study # 11: Radioactivity and Other Constituents in U.S. Geological Water Samples (1960)-- During 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 #5: Chromate and Zink in Sandia Canyon (1969-1970)-- During 1969 and 1970, LASL (H-8 Group) reported hexavalent chromium and zink levels in groundwater samples collected from monitoring wells located in Sandia Canyon (Kennedy, 1971).

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# 6. PRIORITIZATION OF RADIONUCLIDE RELEASES

## 6.1 Estimated LANL Airborne Plutonium Releases

The estimates of airborne plutonium releases from LANL used in this report now include estimates of contributions from D Building prior to 1948. In the previous version of this report, it was noted that measurements or estimates of D-Building releases during these early years had not been located, but were possibly significant. In the interim, a method for estimation of airborne releases from D Building was developed that makes use of indoor (room) air concentration measurements, the only measurements that have been found by the project team. The method is described earlier in this draft report and in Appendix B, and constitutes a major addition to the present revision.

The plutonium release estimates used earlier were also lacking estimates for 1979 and 1980. The LANL effluent summaries for these years have since been located and reviewed, and are included in the release estimates used in this report.

The plutonium release estimates used in this report also reflect the application of two factors to account for filter paper alpha-particle burial and sample line loss (Filter Burial & Sample Line Loss, *LAHDRA Project memo*, Burmeister, 2001). The filter burial factor accounts for the fact that, when alpha-emitting particles impinge on air sampling media (filter "papers"), a fraction of the particles bury themselves in the media to an extent that some alpha particles given off will not reach a radiation detector placed nearby. When the media are counted, observed count rates must be adjusted to account for the burial; otherwise the observed count rates would lead to understatement of quantity of radioactivity that has actually been collected. Two memos from H-4 Division were found that discussed the amount of alpha activity "lost" due to the effect of deposition in the sample filter medium. These memos stated that, for the HV-70 filter paper used until late 1981, the amount of alpha activity lost was 37.6%. This yields a correction factor of 1.603; that is, reported activity levels must be multiplied by this number to correct for the effect of burial in the sample medium.

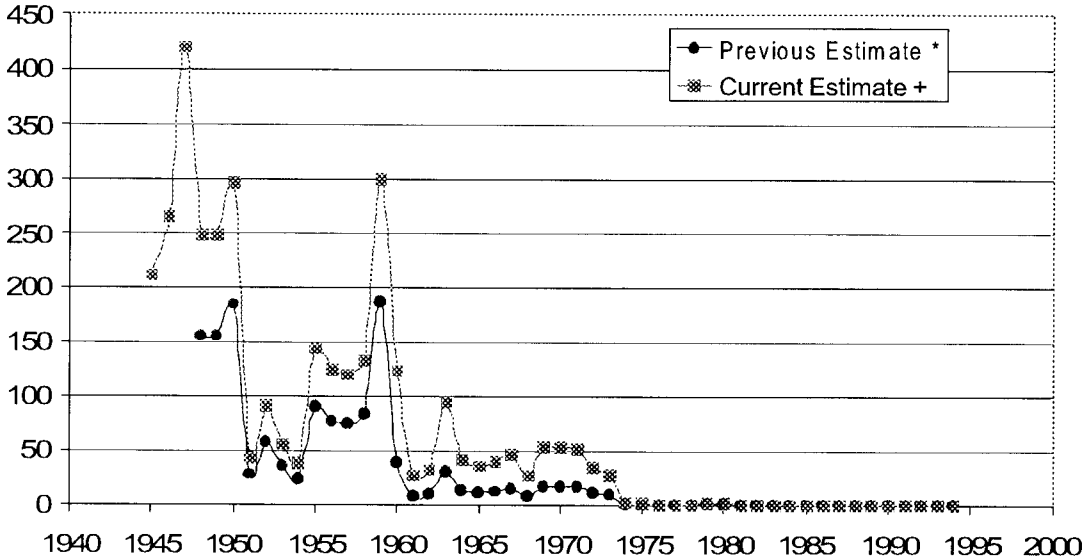
The sample line loss factor accounts for the fact that, when particles are entrained into the flow through a sample line, a fraction of the particles become attached to the walls of the sample line, react with components of the sample line or its other contents, or settle out from the gas stream. As a result, concentrations that exit the sample line can be significantly reduced from concentrations at its inlet. Line-loss factors are often used to adjust measured concentrations to account for these effects so that concentrations in the actual effluent stream are not underestimated. A preliminary value for this correction factor was chosen after conversations with ES&H personnel concerning the appropriate magnitude of these corrections and when they were first applied to release totals reported by LANL. The value selected by the project team for the multiplicative line-loss correction factor is 2.0, a value that may be adjusted as more information becomes available.

Filter burial and sample line loss are familiar concepts today, but it could not be determined precisely from reviewed documents or interviews conducted to date when factors were first applied by LANL personnel to account for the associated effects on effluent measurements. Some preliminary questioning of ES&H staff revealed that factors to correct for the phenomena were first applied by LANL personnel in the mid-1970s. As a result, the estimates used in this report reflect application of the two correction factors by the project team to reported releases from 1948 through 1975. The estimates given in Table 20 and Figure 11 are still largely based on LANL reported summaries. Except for the estimation of D-Building releases before 1948, no independent determination of released activity has been made from monitoring data.

**Table 20: Estimated LANL Airborne Plutonium Releases (millicuries)**

| (mCi) Year | Previous | Current |
|---|---|---|
| 1943 | | |
| 1944 | | |
| 1945 | | 211.41 |
| 1946 | | 264.73 |
| 1947 | | 420.54 |
| 1948 | 155.00 | 248.47 |
| 1949 | 155.00 | 248.47 |
| 1950 | 185.00 | 296.56 |
| 1951 | 27.00 | 43.28 |
| 1952 | 57.01 | 91.38 |
| 1953 | 35.23 | 56.47 |
| 1954 | 23.30 | 37.35 |
| 1955 | 89.89 | 144.09 |
| 1956 | 77.49 | 124.22 |
| 1957 | 75.12 | 120.41 |
| 1958 | 83.21 | 133.39 |
| 1959 | 187.24 | 300.14 |
| 1960 | 38.27 | 122.69 |
| 1961 | 8.16 | 26.16 |
| 1962 | 9.79 | 31.40 |
| 1963 | 29.59 | 94.88 |
| 1964 | 13.01 | 41.70 |
| 1965 | 10.90 | 34.94 |
| 1966 | 12.32 | 39.50 |
| 1967 | 14.51 | 46.53 |
| 1968 | 8.24 | 26.43 |
| 1969 | 16.73 | 53.63 |
| 1970 | 16.42 | 52.65 |
| 1971 | 16.11 | 51.66 |
| 1972 | 10.69 | 34.28 |
| 1973 | 8.70 | 27.88 |
| 1974 | 0.79 | 2.55 |
| 1975 | 0.25 | 0.79 |
| 1976 | 0.07 | 0.07 |
| 1977 | 0.13 | 0.13 |
| 1978 | 0.11 | 0.11 |
| 1979 | 1.09 | 1.09 |
| 1980 | 0.75 | 0.75 |
| 1981 | 0.06 | 0.06 |
| 1982 | 0.11 | 0.11 |
| 1983 | 0.11 | 0.11 |
| 1984 | 0.14 | 0.14 |
| 1985 | 0.21 | 0.21 |
| 1986 | 0.21 | 0.21 |
| 1987 | 0.07 | 0.07 |
| 1988 | 0.07 | 0.07 |
| 1989 | 0.05 | 0.05 |
| 1990 | 0.03 | 0.03 |
| 1991 | 0.04 | 0.04 |
| 1992 | 0.01 | 0.01 |
| 1993 | 0.01 | 0.01 |
| 1994 | 0.01 | 0.01 |
| **Total** | **1368** | **3432** |

**Figure 11: Estimated Annual Airborne Plutonium Releases from LANL (mCi)**




* Based on LANL summaries.
\+ Based on LANL summaries, but with the addition of project team estimates for D-Building releases 1945-1947 and application of corrections for filter burial and sample line loss 1948-1975.

## 6.2 Prioritization of Airborne Radionuclide Releases

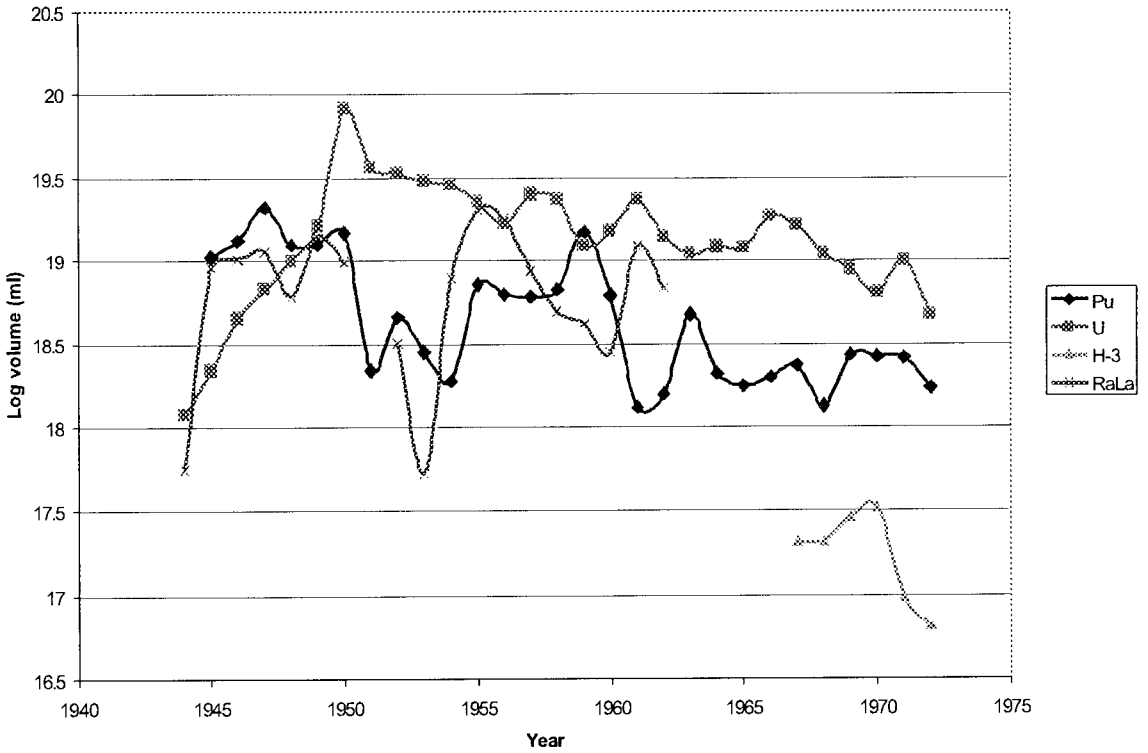
As part of beginning the process towards prioritizing or ranking the historical releases identified to date, the reported estimates of annual quantities of each radionuclide released were divided by their respective concentration limits from Title 10 of the Code of Federal Regulations, Part 20, Appendix B. The results were estimates of the volumes of air that would have been required to dilute the released radioactivity to allowable concentrations on an annual average basis. These values of "dilution air volume required" (or logarithms of those volumes) can be used as a preliminary method to compare the relative importance of releases across radionuclides and facilities.

It is important to remember that this simple method of prioritization does not take into account decay of the radionuclides, dilution and dispersion during airborne transport, or the different exposure routes that were likely important for the various radionuclides. If later phases of the CDC dose reconstruction process are conducted, these elements will be studies in detail based on as much site-specific data as are identified during this information gathering phase.

In Figure 12, the airborne priority for some significant nuclides is given over the time period from 1943 to 1972. It can be seen that airborne uranium has a greater priority than airborne plutonium for almost all years.

**Figure 12: Airborne Priority for Some Significant LANL Radionuclides, 1943 – 1972**

(As indicated by required air dilution volumes, on a log scale)



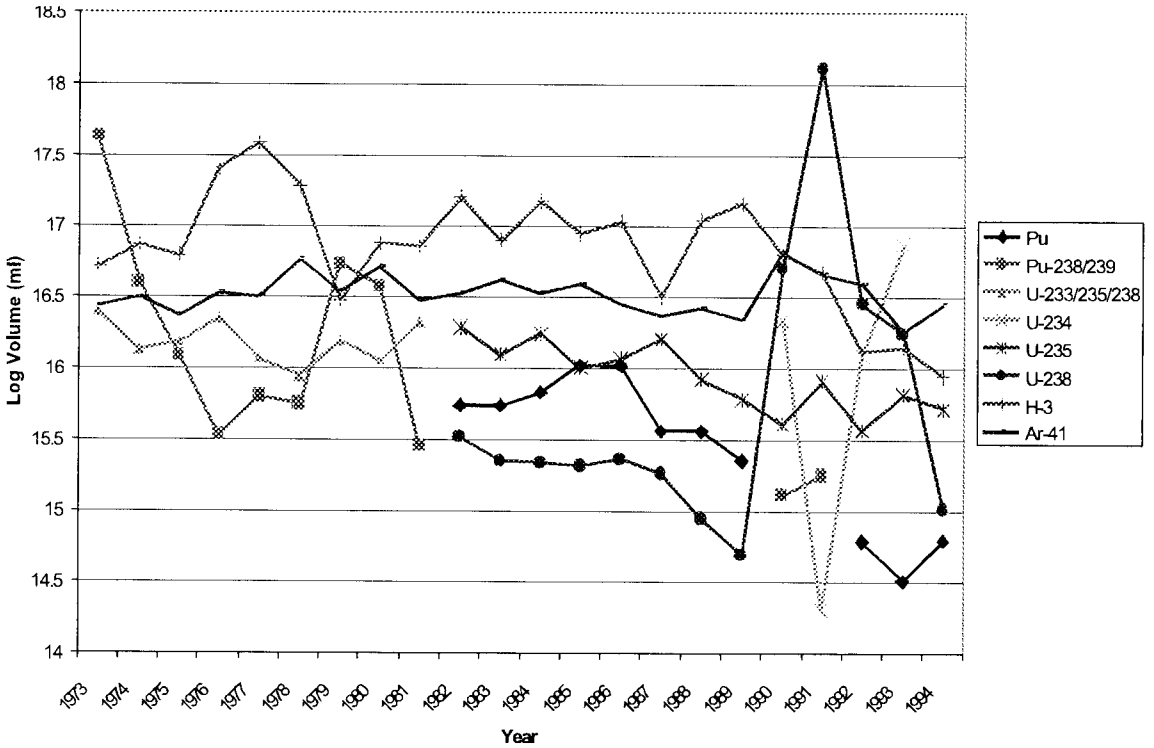

The previous version of this priority comparison showed that plutonium had a greater priority than all nuclides considered. The present analysis now includes the radioactive lanthanum (RaLa) that was used at TA-10 in the RaLa program. This version also includes the uranium that was used in the test shots at TA-10, 15, and 16; this uranium is the predominant contributor to the above priority. The plutonium releases reflected in Figure 12 include the D-Building estimate for years before 1948, the lack of which was discussed as a shortcoming in the previous version. The uranium and plutonium releases also used here also reflect the application of the correction factors for filter paper burial and sample line loss, except for in the case of the uranium released in test shot work.

The uranium from the test shot work was simply blown up in the tests on explosive compression. This uranium had its natural enrichment of $^{235}U$ or was possibly depleted in this isotope. The summaries for these years gave only the curies of uranium used, and the entire amount for each year was used in the calculation of the priority. That calculation ignores questions of particle size creation and agglomeration, local fallout and deposition. These issues are expected to be significant for explosively generated uranium airborne suspensions, much more significant than for filtered uranium effluents which were a minor part of the priority during this time period.

In Figure 13, an airborne priority plot for the time period 1973 – 1994 is shown for some significant nuclides.

**Figure 13: Airborne Priority for Some Significant LANL Radionuclides, 1973 – 1994.**

(As indicated by required air dilution volumes, on a log scale)



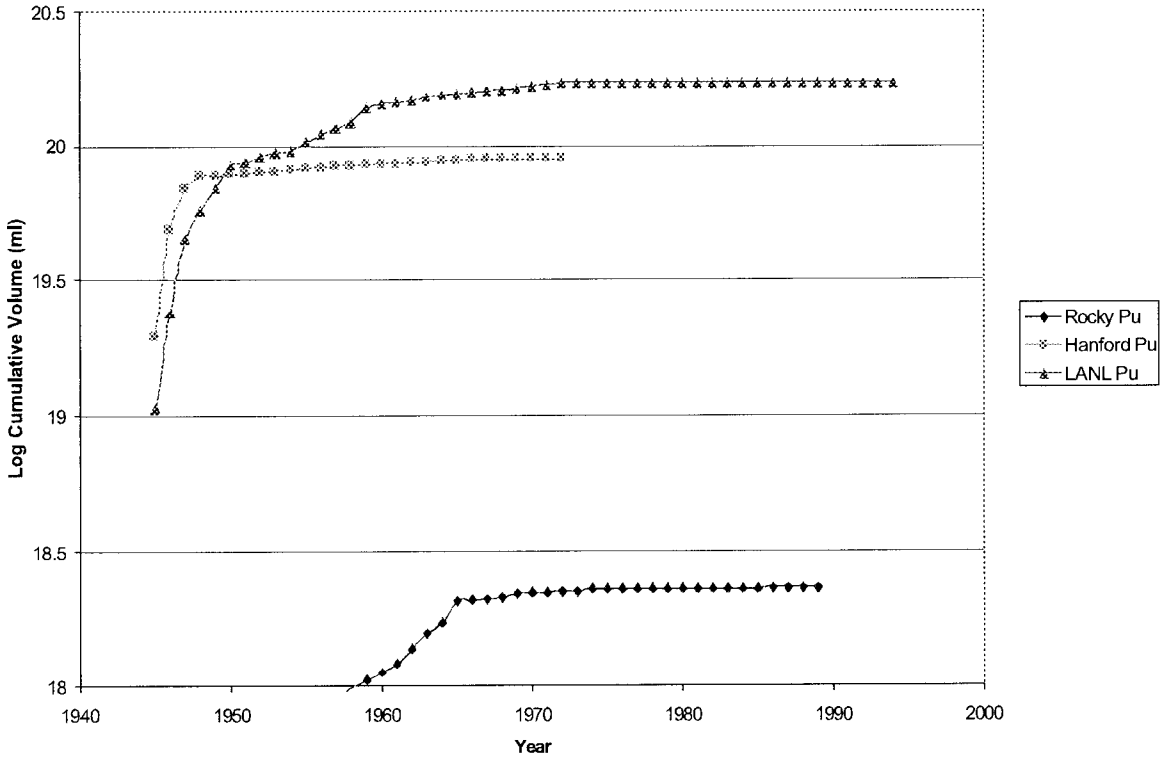

It is evident that plutonium and uranium have a decreased priority in this time period when compared to their priority in Figure 12.

It is informative to rank the major plutonium facilities in the United States in terms of their plutonium effluent releases. In Figure 14 below, the logarithms of the *cumulative* "required air dilution volumes" for airborne plutonium for the three different facilities are displayed. The facilities are Hanford (routine airborne plutonium releases per the Hanford Environmental Dose Reconstruction), Rocky Flats (routine airborne plutonium releases per the Rocky Flats Toxicologic Review and Dose Reconstruction), and LANL (routine plutonium releases estimated by LANL personnel plus Building D model). These three facilities were the major plutonium facilities in the United States. Dose reconstruction efforts have already been conducted for Hanford and Rocky Flats. The dilution volume required was determined as described earlier for the purpose of nuclide prioritization, except that the volumes were summed over time.

The plot below demonstrates that LANL plutonium releases, especially during the early years of LANL operations, may warrant closer examination as more information is gathered and more rigorous prioritization can be performed. The Building D model was part of this examination in order to treat the years prior to 1948 that were lacking from the previous prioritization.

**Figure 14: Ranking Plot of Routine Rocky Flats, Hanford, and LANL Airborne Pu Releases**

(As indicated by *cumulative* required air dilution volumes, on a log scale)




Other Issues Affecting Ranking of Airborne Radionuclide Releases

The results reported above for the priority of plutonium do not include certain effects such as:

1) The TA-21 stacks were not HEPA filtered until the mid-seventies, later than the stacks at Rocky Flats. The laboratories at LANL were constructed with filters that were considered state-of-the-art at the time of their construction. By the mid-seventies, however, TA-21 had outlived its usefulness as a plutonium processing facility, and TA-55 took over plutonium processing.

2) LANL traditionally considered the limit on its effluent releases to be the Maximum Permissible Concentration (MPC) at the site boundary, whereas today's regulations considered the MPC at the stack. The dilution afforded by a distant site boundary naturally allows a much larger stack concentration when compared to other facilities that operated under more restrictive conditions.

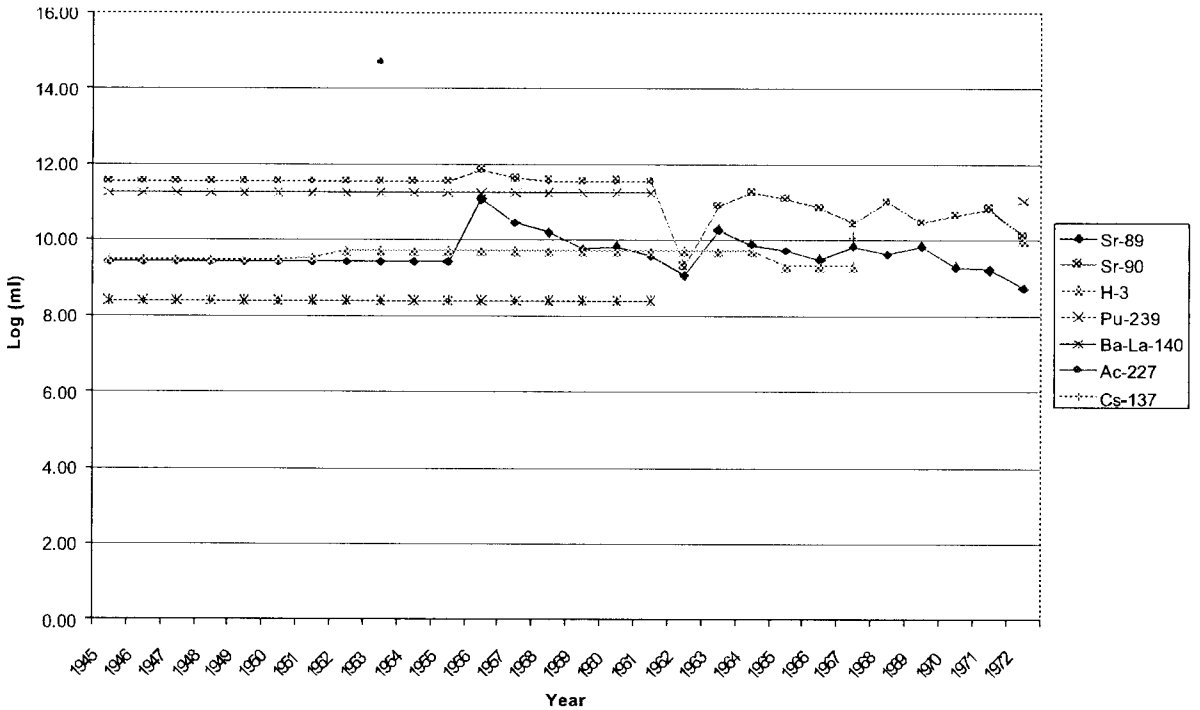
3) Although this revision of the prioritization includes factors to account for filter burial and sample line loss, further research is required to determine the most appropriate values for these factors. Presently, the factors have values that are appropriate for post-mid-seventies operations. The factors have been applied to operations prior to this time period knowing that the actual values were most likely different.

## 6.3 Prioritizing Waterborne_Radionuclide Releases

In the initial approach to prioritizing past waterborne radionuclide releases, reported release totals presented earlier in this report were divided by their respective maximum allowable effluent concentrations from 10CFR20, Appendix B. This yielded a value for the volume of liquid needed to dilute each radionuclide quantity to an allowable concentration on an annual average basis, and allows comparison of the waterborne radionuclides in terms of their relative importance or priority. Figure 15 is a plot of the time history of this required dilution volume on a log scale.

**Figure 15: Required Dilution Volume for LANL Waterborne Radionuclide Releases**

(As indicated by required water dilution volumes, on a log scale)



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Heeb, C.M. Radionuclide Releases to the Atmosphere from Hanford Operations, 1944 - 1972. PNWD-2222 HEDR. UC-000. Draft. January 1994.

LANL. *TA-21 Operable Unit RFI Work Plan for ER.* Vol. I - III. 1991.

# 7. PRIORITIZATION FOR CHEMICALS

## 7.1 Current Chemical Inventory

LANL maintains an inventory of chemicals present on-site called the Automated Chemical Inventory System (ACIS). Information on the quantities and types of chemicals used at LANL was collected starting in 1991 and the Microsoft Access® database was completed in 1993 (ESH, 1-6-99). ACIS has been updated annually since 1994. The 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. SecureID cards for members of the project team have been obtained. Access to the database will allow the project team to compile the information in different ways, and will provide details such as the specific locations of chemicals through database search capabilities. In the interim, 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. The database contains approximately 120,000 records. More recently, access through a Web interface was granted to allow limiting searches to be performed. A request has been made for an official-use-only copy of the database for performing more complex searches. The database does not include radionuclides, explosives, beryllium, depleted uranium, or other bulk metals. It contains many trade name products with no information on 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 represented the largest onsite quantities. Twelve of the thirteen chemicals present onsite in the highest quantities do not have USEPA recommended toxicity values for potential cancer and noncancer systemic health effects, although some can be irritants or corrosives at high concentrations. They are shown in Table 21 in order of decreasing approximate onsite quantities.

Of the 37 high quantity chemicals, the 13 with USEPA recommended toxicity values are also shown in the following table in ranked 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 we do not know at this point how the chemicals are used and their potential for release to the environment.

Future document review activities and interviews with LANL staff, and information from the occupational Chemical Exposure Assessment Program will identify the uses and release potential for these inventory chemicals. Site personnel have agreed to provide members of the project team access to site files of Material Safety Data Sheets for the trade name products to determine if they contain any hazardous materials. The remaining inventory chemicals will be analyzed for quantity and toxicity characteristics once access to the electronic database is granted. For chemicals that could be released to the offsite environment as a result of their use, air 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 offsite populations using site-specific assumptions regarding dispersion, transport and exposure. The threshold quantity approach will be used to focus data gathering efforts on those chemicals for which the onsite inventory quantity exceeds the threshold quantity.

**Table 21: Selected Data from a Current LANL Chemical Inventory**

| Chemical | Onsite Quantity | Toxicity Ranking |
|---|---|---|
| Nitrogen | $4.2 \times 10^7$ litres | -- |
| Argon | $3.8 \times 10^7$ litres | -- |
| Helium | $3.7 \times 10^7$ litres | -- |
| Hydrogen | $1.6 \times 10^6$ litres | -- |
| Oxygen | $1.6 \times 10^6$ litres | -- |
| Propane | $1.3 \times 10^5$ litres | -- |
| Sulfuric acid | $2.2 \times 10^4$ litres | -- |
| Toluene | $2.1 \times 10^4$ litres | 8 |
| Sodium hydroxide | $1.5 \times 10^4$ kg | -- |
| Sodium chloride | $8.6 \times 10^3$ kg | -- |
| Ethyl alcohol | $7.1 \times 10^3$ litres | -- |
| Sodium carbonate | $6.8 \times 10^3$ kg | -- |
| Hydrochloric acid | $6.6 \times 10^3$ litres | -- |
| Acetone | $6.2 \times 10^3$ litres | 7 |
| Ethylene glycol | $5.1 \times 10^3$ litres | 12 |
| Chlorodifluoromethane | $4.8 \times 10^3$ litres | 14 |
| Methyl alcohol | $2.8 \times 10^3$ litres | 10 |
| Nitric acid | $2.6 \times 10^3$ litres | -- |
| Isopropanol | $2.2 \times 10^3$ litres | -- |
| Hydrogen peroxide | $7.8 \times 10^2$ litres | -- |
| Buffer solutions | $6.3 \times 10^2$ litres | -- |
| Acetic acid | $5.8 \times 10^2$ litres | -- |
| Hexane | $5.4 \times 10^2$ litres | 5 |
| Methylene chloride | $4.9 \times 10^2$ litres | 4 |
| Miscellaneous chlorofluorcarbon products | $4.6 \times 10^2$ litres | -- |
| 1,1,1,2-Tetrafluoroethane | $4.4 \times 10^2$ litres | -- |
| Photographic developer products | $3.9 \times 10^2$ litres | -- |
| Dimethyl sulfoxide | $3.8 \times 10^2$ litres | -- |
| Chloroform | $3.4 \times 10^2$ litres | 1 |
| Benzene | $2.1 \times 10^2$ litres | 2 |
| Ether | $2.0 \times 10^2$ litres | 9 |
| Dichlorodifluoromethane | $1.5 \times 10^2$ litres | 6 |
| Photographic fixer products | $1.2 \times 10^2$ litres | -- |
| Tetrahydrofuran | $6.0 \times 10^1$ litres | 3 |
| Ethylenediamine tetraacetic acid | $3.8 \times 10^1$ kg | -- |
| Ethyl acetate | $2.1 \times 10^1$ litres | 11 |
| 1,1-Difluoroethane | $8.5 \times 10^0$ litres | 13 |

## 7.2 Historical Chemical Inventories

Harry Schulte, a former Industrial Hygiene group leader, is reported to have conducted a chemical inventory in the early 1970s (ESH, 1-6-99). A draft report was prepared, but was never finalized. It was suggested 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 do not have any copies in their possession. To date, this information has not been located by the project team.

For years prior to the initiation of the current chemical inventory program, the project team identified several lists of chemicals used at LANL. The lists represent the years 1948, 1971, 1977, and 1985. No quantities or locations of use are provided.

Table 22 is a list of chemicals documented as having been used at LANL at some point in time. This list was compiled from the LANL documents that have been reviewed to date, entered into the project database, and released to the public. Copies of many of the reviewed documents have not yet been obtained by the project team from the site. Classification, privacy act, and legal privilege reviews are required prior to public release. Documents used to identify the chemicals in Table 22 are included in the reference section and are described below.

Table 23 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, Rep. No. 1197, is a third source of the same numbers provided in Rep. Nos. 610 and 1324. It states that the amount of airborne solvents is taken from LASL stock issue records. However, it is reasoned that all of the volatile solvents will in time become airborne no matter what the disposal method. Therefore, it appears that 100% volatilization was assumed. The chemicals listed in Table 23 are 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 23, 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.

**Table 22: Chemicals Historically Used at LANL**

| | |
|---|---|
| **Elements** | **Inorganics** |
| antimony | asbestos (magnesium silicate) |
| arsenic | bromide |
| barium | cyanide |
| beryllium | hydrochloric acid |
| cadmium | hydrofluoric acid |
| chromium | nitric acid |
| copper | oxalic acid/ oxalate |
| fluoride | perchloric acid/ perchlorate |
| gallium | phosphoric acid |
| iron | sodium hydroxide |
| lanthanum | sodium thiosulfate |
| lead | sulfuric acid |
| lithium | |
| manganese | **Semi-Volatile Organics** |
| mercury | n-butyl acetate |
| molybdenum | ethyl acetate |
| nickel | hexachlorobutadiene |
| niobium | naphthalene |
| platinum | PCB (polychlorinated biphenyls): Aroclor 1242 |
| samarium | |
| silver | **Explosives** |
| tantalum | Baratol (mixture of barium nitrate and TNT) |
| thallium | Comp. B (mixture of 60% RDX and 40% TNT) |
| uranium (normal and depleted) | Cyclotol (mixture of 70-75% RDX and 25-30% TNT) |
| vanadium | Explosive D (ammonium picrate; ammonium-1,3,5-trinitrophenol) |
| zinc | HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) |
| zirconium | nitrobenzene |
| | nitrocellulose |
| **Volatile Organic Compounds** | NQ (nitroguanidine; Picrite) |
| acetone | Octol (mixture of 70-75% HMX and 25-30% TNT) |
| benzene | Pentolite |
| carbon tetrachloride | PETN (pentaerythritol tetranitrate) |
| ethanol | picric acid |
| methanol | PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine) |
| methyl chloroform (chlorothene) | RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) |
| methyl chloride (chloromethane) | TATB (1,3,5-triamino-2,4,6-trinitrobenzene) |
| methyl ethyl ketone (2-butanone) | Tetryl (1,3,5-trinitrophenyl-methylnitramine) |
| methylene chloride (dichloromethane) | TNT (2,4,6-trinitrotoluene) |
| tetrachloroethylene (perchloroethylene) | Torpex |
| tetrabromoethane | |
| tetrahydrofuran | |
| toluene (toluol) | |
| trichloroethylene | |
| xylene | |

# DRAFT

## Table 23: 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 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6800-13,600 | -- | -- | -- | -- | -- | -- | -- |
| | Sulfur hexafluoride | 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. not assigned).
[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).

### 7.3 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 (LANL 1990), the unit, waste and releases information sections were reviewed by the project team to identify additional chemicals that may have been released from LANL.

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 (USDOE 1996) describes historical activities at the potential release sites involving the following chemicals: asbestos, barium, lead, depleted uranium, beryllium, and PCBs. High explosives, organic solvents, and ordnance are also cited but specific chemical names are not provided.

The project team has been following Environmental Restoration (ER) activities at LANL since the project began in February 1999. Numerous press releases and fact sheets regarding environmental investigations and surveillance activities have been provided by the ER Project. For example, oxalic acid 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 1998). 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 (Dobratz 1995) and in nuclear chemistry analyses conducted in CMR Building.

Explosives including HMX, RDX, and TNT 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 the construction of 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 solids were trucked to a burning ground, filtered through sand, then dried and ignited. The filtrate was treated before being discharged. Solvents such as acetone, methanol and ethanol were released to the atmosphere by volatilization from the water discharged at the outfalls (LANL 1998,1999).

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 (author and date unknown) 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. 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 24.

**Table 24: 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 | 168,250 | 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. not yet assigned).

[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 are disposed of at TA-16 by open burning. Explosive burning experiments conducted at LASL 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 (Drake 1971b) includes several explosives dispersed at TA-40 as gaseous detonation products during the period July – September 1971 (Table 25). Toxic material reports for December 1979 through September 1980 (Dinegar 1980) report the approximate amounts of HE exploded per month in WX-7 shots at TA-40 and TA-22.

**Table 25: 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 lbs) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Comp B | 34 kg (75 lbs) | 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 lbs) | 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 kg | 19 kg | 37 kg | 44 kg | 49 kg | 32 kg | 54 kg | 1 kg | 174 kg | 18 kg |

-- not reported

Research and development, and testing of high explosives were conducted at more than 25 different Technical Areas of LANL (Goldie 1984; LANL 1990). 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 (HAI 1993; Johnson and Dahl 1977) were released to the environment as a result of test shots conducted at LANL since the 1940s. Drake and Eyster (1971) estimate that between 75,000 and 95,000 kg of uranium have been expended in experimental shots at LANL from 1949-1970. Normal uranium was used until 1954, then depleted uranium was used exclusively. The estimate does not address where the uranium went, only that they don't have it any longer. A 1952 AEC report states that test shots at LASL routinely dispersed 300 lbs of uranium per month and 200 lbs of barium per month (English 1952). Two 1971 memoranda (Drake 1971a) report toxic materials dispersed by GMX Division shots for April and May 1971 as shown in Table 26.

**Table 26: Materials Dispersed by GMX Division Shots for April and May 1971**

| Toxic Material | April 1971 | May 1971 |
|---|---|---|
| Uranium-238 | 171 kg (376 lbs) | 142 kg (312 lbs) |
| 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 that have been identified by the project team to date are logbooks of analytical results with unidentified sampling locations. Several documents describe storage and disposal of 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 (Unknown 1997; LANL 1993). 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 lbs/day 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. Rep. No. 645 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.

Rep. No. 645 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 gpm. The document states this resulted in the discharge of 20 pounds of sulfuric acid and 1.4 pounds of hexavalent chromium to the atmosphere per 24 hour period.

Draft CEARP documents from 1986 (Rep. No. 525) report a staff member recalling the use of potassium dichromate in the cooling tower water prior to a time when the heat exchanger components were changed from aluminum to steel. The employee stated that mist from the tower would drift about the site and turn things green. This "greening" effect went away with the switch to steel components (and the subsequent reduction in use of potassium dichromate). The use of potassium dichromate as a corrosion inhibitor is confirmed in Rep. No. 645, which states that the blowdown discharges from the cooling tower (~60,000 gallons per week) included approximately 14.5 pounds of hexavalent chromium. This same document reports that the blowdown also included 3 pounds of chlorophenol biocide and 200 pounds of sulfuric acid in the form of sulfate salts (used for pH control). The blowdown from the demineralizer loop heat exchanger contributed another 20 pounds of sulfuric acid and 0.5 pound of chlorophenol biocide. Rep. No. 645 also says it was planned to make the switch from aluminum to stainless steel components in fiscal year 1974 to reduce to amount of corrosion inhibitor required and thus reduce the amount of

hexavalent chromium in the blowdown water. An inventory of pollutant releases to the environment for 1971 (Rep. No. 883) 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, which was 2500 times the quality standard of 0.01 mg/l for that era. The same effluent stream is reported to contain total dissolved solids at an average concentration of 800 mg/l, which also exceeded the applicable quality standard of 500 mg/l.

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 windshields on people's cars had to be replaced (G. Neely, 1999 personal communication). Condensate poured on the ground; there is a tree in the area with Cs-137 in its leaves as a result. There is/was reportedly also asbestos in some TA-2 buildings.

Rep. 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. This report also mentions that routine monitoring for mercury vapor had been going on at the Clementine site prior to this incident.

Rep No. 2201 reports that a mercury spill occurred at the Clementine site between January 20, 1951 and February 20, 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, it was reported that members of H Division had been participating in conferences relative to the large quantity of contaminated mercury to be pumped from the fast reactor at Omega Site. Since the material was contaminated with plutonium, it appeared to the participants that the plutonium hazard was more serious than that of the mercury vapor. [Repository No. 124]

Accident/ incident reports for only a few years have been identified by the project team to date, specifically 1979, 1986, 1990, and 1991. 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. However, details regarding building locations, quantities used, or the operations involved are rarely provided. All of the chemicals mentioned are included in Table 4.

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Enders, J. CMR weekly and monthly reports, 1960-70. Rep. No. 919/2072. [tetrahydrofuran, tetrabromoethane]

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LANL. High-Explosives Wastewater Treatment Facility- An environmental success story [HE, acetone, methanol, ethanol]. LALP-98-84. 1998.

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LANL. Laboratory detects perchlorate in shallow groundwater. LANL News Release. March 2, 2000.

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Schulte, H.F. Industrial Hygiene Progress Reports, 1949-1950. Rep. No. 668. [naphthalene]

Unknown author. Summary of wastes and effluents at Omega Site (TA-2). August 27, 1973. Rep. No. 645. [chromium]

Unknown author. Chronological record of accidents at LASL. 1979. Rep. No. 514.

Unknown author. PCB cleanup at TA-3 (OU#1114), 1995-97. Rep. No. 1094.

Unknown author and date. Disposal of hazardous materials by burning. Central Records Center. Rep. No. 672.

U.S. Congress. Office of Technology Assessment. Complex Cleanup- The environmental legacy of nuclear weapons production. February 1991.

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# APPENDIX A: DISCUSSION OF THE HUMAN TISSUE ANALYSIS PROGRAM

Background

The human tissue analysis program was a 35-year-long effort by Los Alamos National Laboratory to study the levels of plutonium in workers and in the general population of the United States. The general population was exposed to plutonium from atmospheric testing of nuclear weapons. Populations located near plutonium facilities, such as the D Building and the DP Site in Los Alamos, were also exposed to plutonium released during operations.

Compilations of the autopsy data have been published periodically, and Los Alamos Science Magazine summarized the program in the November 23, 1995 issue that was devoted to a discussion of the Human Radiation Experiments. That issue is available on the LANL Library's Web page.

The data have been analyzed by Los Alamos personnel and have been used to demonstrate that the differences between states in the median values of plutonium concentration in tissue were small. 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, as compared to other states.

Exposures to weapons testing fallout plutonium in an area would likely be similar for most individuals (with similar lifestyles); however, exposures to releases from plutonium facilities would likely not be similar, since individuals residing closest to the facility would have greatest exposure to releases. These individuals might be a small subset of the total population. This subset (individuals residing close to a nuclear facility) might not significantly alter the median value.

The LAHDRA project is attempting to prioritize the releases from LANL. This effort appears to indicate that plutonium releases from DP Site and D Building were relatively high in the 1940s and 1950s. However, some of the data from the 1940s are not available as effluent (stack) measurements, but rather as indoor air concentrations. Several factors are needed to use these data to estimate effluent totals, and the uncertainties in the values for these factors might be quite large. The human tissue analysis program data (even if they do not show any added plutonium in tissue over that expected from global weapons testing fallout) might provide a means to place bounds on the potential plutonium source term from LANL.

Dose Estimates from Exposure of Organs to Plutonium

The autopsy data are provided for various organs in unit of disintegrations per minute (dpm) per kilogram of organ. The following material is presented to explain what these units (dpm/kg organ) mean in terms of radiation dose or health risk.

A fraction of the plutonium present in air is retained in the lungs. The lungs retain the plutonium for a period of time of about a year. Thus, the autopsy data for lung tissue largely reflect the plutonium air concentrations over the last few years prior to death. Since most of the autopsies are from the 1960s and 1970s, the lung data largely reflect intakes due to fallout from the atmospheric testing of nuclear weapons. The largest plutonium releases from Los Alamos apparently occurred in the 1940s and 1950s. This plutonium, if measurable, would no longer be present in lung at the time that most autopsies in the program were performed.

The ICRP 30 model of plutonium behavior in the human body indicates that, of the plutonium present in systemic circulation, 45% goes to the liver, 45% goes to bones, and the remainder is largely excreted. Small fractions of the plutonium uptake are assigned to other organs. The liver and skeleton retain the plutonium for decades. ICRP Report 23's "Reference Man" notes that thoracic vertebrae are 75% trabecular bone, the spongy bone where marrow resides. Thus, the vertebrae and liver are appropriate tissues to sample to measure long-term plutonium deposition in an individual. The program at LANL sampled these two tissues, along with other tissues such as lung.

The autopsy data are provided in the units of dpm/kg organ. It may be of some use to understand the potential doses that are involved with the measured data. The dose, in rem per dpm/kg 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 of liver tissue for each dpm that is incorporated into the body.

A conversion for the skeleton depends on the type of tissue sampled. The entire skeleton ranges from 10% to 20% trabecular by weight. If the tissue sample had the same proportions, one could divide by about 2 kilograms (or 20% of the 10 kg total mass of skeleton) to yield 0.225-dpm/kg skeleton. It has also been noted that the plutonium concentration in bone (from humans) is inversely proportional to the percent bone ash (Kathren et. al., 1991). Plutonium is concentrated in the trabecular bone rather than the hard, compact, cortical bone. Each person is, of course, unique, and their weights are not the same as the average that is expressed in Reference Man. The LANL compilations of autopsy data provide the dpm/kg for the actual individual's organ size, and also express the data adjusted to what would be present in an organ of the size stated in Reference Man.

The dose resulting from the 1 dpm systemic uptake depends on the chemical form of the intake (and of course the isotope, particle size, etc.). For inhalation of $^{239}$Pu oxide, Federal Guidance Report 11 asserts a dose factor of $8.21\times10^{-4}$ Sv/Bq for bone surfaces, which converts to 1.37 mrem/dpm (intake). Dividing 1.37 mrem by 0.225-dpm/kg skeleton then gives 6 mrem committed bone dose per dpm/kg skeleton.

The committed effective dose equivalent (CEDE) is a measure of radiation dose that supports estimation of risk by adding the doses to be received by all of the organs (weighted for their relative susceptibilities to 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 CEDE per dpm/kg skeleton, or 0.6 mrem CEDE per dpm/kg liver. For more soluble forms (inhalation Class W), the values for $^{239}$Pu are 16 and 0.9 mrem per dpm/kg skeleton for bone surfaces and CEDE, respectively. Values for $^{238}$Pu are similar to those for $^{239}$Pu.

A simplification that expresses the results in the right "ballpark" would be that 1 dpm/kg in the liver or vertebrae results from the autopsy program is roughly equivalent to 1 mrem CEDE.

Levels of Plutonium from Weapons Testing Fallout

Plutonium deposition from worldwide fallout near Los Alamos has been reported by Purtymun et al. (1990). Soil and river sediment samples were taken, and results were reported in units of concentration, fCi/g. One can convert the concentration measured in a soil sample to areal deposition by multiplying the concentration by the mass of soil sampled and dividing by the total area of the sample. This conversion is needed to enable comparison of the LANL measurements of weapons test fallout with those taken by the Environmental Measurements Laboratory as reported by Krey for the Denver area (1976). Krey reported fallout for the Denver area as $1.7 \pm 0.5$ mCi/km$^2$. Krey's data did not include the contribution to fallout from Chinese weapons testing in the late 1970s that may be reflected in the LANL data from the early 1980s. Krey's data would also not have reflected any of the weathering that might have occurred between the time of the sampling near Denver and the sampling around Los Alamos.

Each of the sites sampled by LANL consisted of a 9-meter square, with soil collected from each corner and the center. The sample collected at each point was 7.5 cm in diameter and 5 cm deep. The samples were combined to form a composite sample. The total volume of soil collected was 1100 cc, which would weigh nearly 2 kilograms at a soil density of 1.8 g/cc. The area collected was 221 square centimeters.

Los Alamos asserted a total plutonium release from the site of 1.2 curies in the 1979 Final Environmental Impact Statement for the site (DOE/EIS-0018, 1979). This activity could contaminate an area of 1200 square kilometers (or the area within about 20 km) to a level of about 1 mCi/km$^2$ assuming complete fallout. Thus, the sampling for "background" levels of plutonium in Los Alamos from weapons testing would best have been conducted beyond 20 kilometers to avoid having the results be significantly impacted by LANL operations.

Six sites at about a 50-mile radius from Los Alamos were sampled in 1981 and 1983, and additional locations along the continental divide were sampled in 1986. The average of all $^{239}$Pu results for the six sites about 50 miles from Los Alamos was 8.75 ± 5 fCi/g. This corresponds to 0.8 ± 0.5 mCi/km$^2$ when corrected to areal deposition. The total integral level of weapons test fallout plutonium for the Los Alamos area appears to be about one-half of that for Denver.

The Autopsy Data

The autopsy data reported by McInroy et al. in 1979 in *Health Physics* show that the cumulative frequency distributions of liver concentrations (dpm/kg liver) are nearly identical between Los Alamos and Denver. These data are shown in Figure A-1. The vertebrae autopsy samples from Los Alamos are higher than Denver (Figure A-2). To permit easy comparison, the figures were scanned in and the data for Los Alamos and Denver were superimposed on one graph.

While the Los Alamos area appears to have had one-half (or less) of the weapons test fallout experienced near Denver, the liver results (equal liver concentrations) do not reflect lower plutonium uptake near Los Alamos. This appears to be the case across the studied population, not just in a part of the population. If added plutonium uptake was experienced due to facility operations, one might expect that only a few individuals would be impacted. The vertebrae results show differences, namely higher bone levels than near Denver, with the largest differences in frequency of occurrence appearing in the subpopulations with higher bone concentrations.

The data also show significant divergence in the ratio of concentrations in the skeleton to that of the liver. Figure A-3 shows a cumulative frequency distribution graph for the ratio of vertebrae results to those for liver across all results that had data for both organs. In general, these would be the highest reported data. The results from Denver appear to be log-normally distributed about a median ratio of one, with one person having somewhat more than ten-times as much plutonium in their vertebrae as in their liver. The Los Alamos data have 7 of 15 results greater than ten, with one result approaching a ratio of 1000.

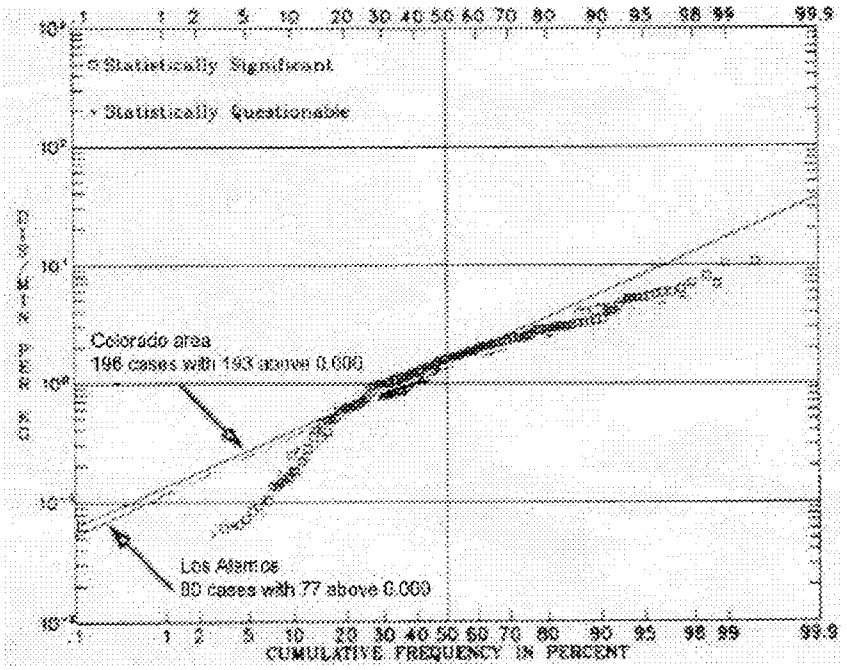


Figure A-1. Liver Autopsy Results

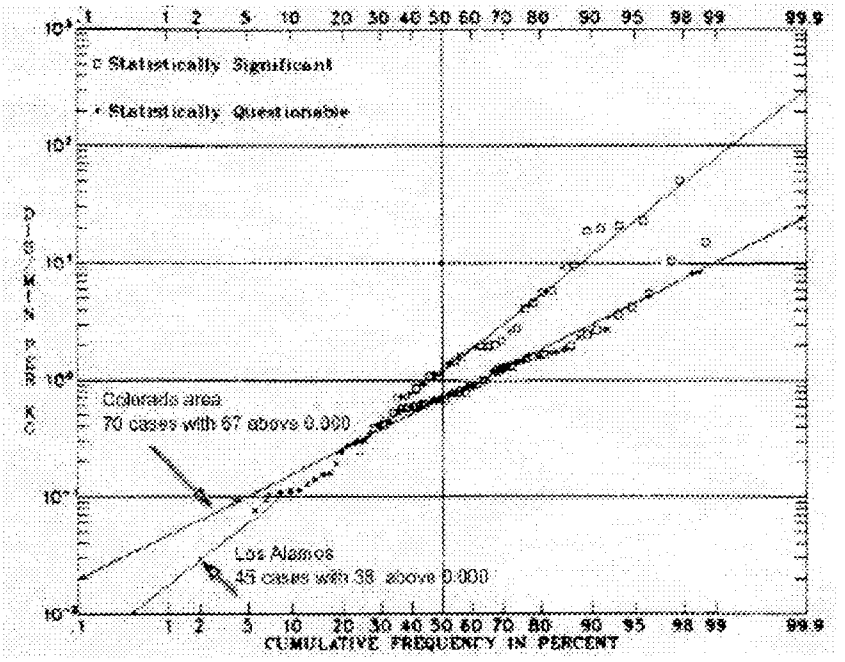


Figure A-2. Vertebrae Autopsy Results

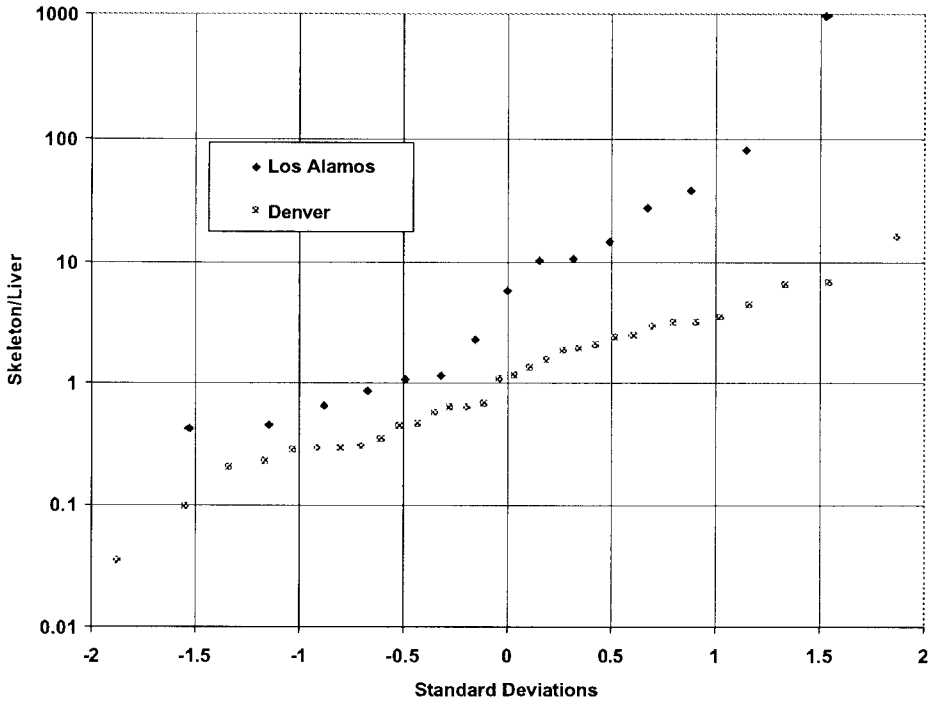


Figure A-3. Cumulative Frequency Distribution of Vertebrae-to-Liver Ratio for Denver and Los Alamos

The ICRP model for plutonium assumes that the skeleton retains plutonium with a biological half-life of 100 years, and the liver retains the plutonium for 40 years. The vertebrae-to-liver ratio would therefore be expected to increase with increasing time after a single plutonium uptake, and high ratios could be indicative of plutonium intakes that occurred relatively long ago.

The LANL human tissue analysis program yielded data that are relevant to assessment of the laboratory's airborne plutonium releases and associated contributions to the plutonium body burdens of area residents. The LAHDRA project team believes that there is merit to considering the use of the autopsy data, along with historical soil deposition measurements like those discussed in this appendix, as components of the analysis to place reasonable and defensible bounds on LANL plutonium releases. This approach may be particularly valuable for periods during which effluent monitoring was not performed.

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# APPENDIX B: METHOD FOR ESTIMATING EARLY D-BUILDING PLUTONIUM RELEASES

### Method for Estimating D-Building Airborne Effluents

The present state of the D-Building release estimation methodology is summarized by the following equations. The equations are described below and their respective terms are detailed in the following sub-sections.

Equation B-1 gives an estimated concentration for airborne effluents given a reported average monthly concentration for a particular room in D Building:

$$\left(\overline{C}_{Room} \cdot F_{Dg} \cdot F_{Di} \cdot F_{B} \cdot F_{Conv} \cdot F_{Hood}\right) \Rightarrow \frac{\mu Ci}{L} \qquad \text{Eq. B-1}$$

Equation B-2 gives an estimated flow rate out of the room and into the air with certain assumptions about room sizes and air change rates. See below for more detailed discussion.

$$\left(A_{Room} \cdot H_{Room} \cdot A_{Ex} \cdot F_{Vol}\right) \Rightarrow \frac{L}{\min} \qquad \text{Eq. B-2}$$

Equation B-3 gives an estimated time in minutes per month that each room was in operation:

$$\left(W_{D/M} \cdot W\right) \Rightarrow \frac{\min}{month} \qquad \text{Eq. B-3}$$

Equation B-4 multiplies the other three to yield an estimate of the activity released for each month for a particular room:

$$\frac{\mu Ci}{L} \cdot \frac{L}{\min} \cdot \frac{\min}{month} \Rightarrow \frac{\mu Ci}{month} \qquad \text{Eq. B-4}$$

In the following sections, the individual terms used in the methodology are described, and their currently assigned values are given. Discussion is also provided about what are the conservative and non-conservative terms as well as what data are needed to refine the method. The major assumptions of the model are next enumerated, and they are discussed in their respective sections.

**Major Assumptions of the Approach**

The D-Building release estimation method is, at present, intended to underestimate the airborne releases. This is motivated by a desire to provide a lower bound for the airborne release from D Building. To accomplish this goal, assumptions were made about the parameters in order to provide a conservative underestimate of the release. The nature of these conservatisms is then discussed.

1. Each room that had a reported average monthly concentration in the monthly reports released airborne plutonium at a concentration given by Equation B-1.
2. The hood concentration factor is 300. See below for more discussion.
3. Each room is assumed to exhaust its entire volume 10 times per hour. This is called the air exchange rate, and is used in Equation B-2.

Average Room Concentration

$\overline{C}_{room}$ is the average room air concentration for a particular room for a particular month in units of counts per minute per liter, c/m/L. These values come from the monthly CM/CMR – 12 reports (Rep. No. 139). The first room air concentration measurements in these monthly reports begin in September 1945 for only five rooms in D Building. The date and the number of rooms deserve further comment.

By December 1943, D Building was occupied with staff, but not until January 1944 did the first few milligrams of reactor-produced plutonium arrive. The first gram-quantity shipment arrived in February 1944, and not until May 1945 did quantity shipments of plutonium arrive[1]. Thus the method lacks room air concentration data for four months, for which it can reasonably be assumed that the level of work was the same as September 1945, if not more.

D Building had more than five rooms. Presently, it is not known how many rooms were dedicated to work with plutonium and uranium in this time period, but from December 1947 on, the identity of a particular room, whether a uranium or plutonium lab, was recorded. Since the current version of the estimation methodology assumes that only the reported rooms released effluent, the number of rooms used in the model is certainly less than the actual number of rooms that released plutonium.

Detector Efficiency for geometry

$F_{Dg}$ is a detector efficiency factor that accounts for the 2p geometry assumption, currently equal to 2.0. In reviewing the H-6 Group's weekly reports for 1951 – 1953, an assumption of 1 count per 2 decays was found (Rep. No. 150).

At some point, the CMR-12 group was reorganized into Group H-6, but the new group kept the same data reporting responsibilities. Prior to 1953, air concentrations had been reported in units of counts. Beginning in 1953, the concentration data were reported in measures of disintegrations. By comparing corresponding data in the two different units, it was found that Group H-6 was assuming a 50% counting

[1] On March 8, 1944 a 20-milligram button of plutonium metal was chemically produced in D Building. On March 23, 1944 a 520-milligram button of plutonium was produced. This button was large enough to be divided into pieces so that various other researchers could determine the chemical, mechanical, and metallurgical properties of the metal.

efficiency, i.e. one count for every two decays. This is the standard assumption to make when a counter only observes 2p steradians (one side of a two-sided source) instead of 4p steradians (both sides).

The estimated activity of a source must include this counting efficiency, and the factor with its value of 2.0 correctly accounts for the efficiency.

Intrinsic Detector Efficiency

$F_{Di}$ is a detector efficiency factor to account for the intrinsic efficiency of the alpha particle counter, currently equal to 1.25. Presently, it is believed that an alpha scintillation counter, similar in principle to the modern Eberline SAC 3 and SAC 4 alpha counters, was used to count the filter papers that came from the air samplers (Filter Queens) used in the room air monitoring. These counters have an intrinsic efficiency of approximately 80%, and the factor with its value of 1.25 accounts for this efficiency.

It is very possible that instead of an alpha particle scintillation counter, a gas ionization counter was used. In this case, the intrinsic detection efficiency is approximately 100%. It is also possible that scintillation counters of that era had an intrinsic detection efficiency less than that of a modern counter. At this time, no information has been found to resolve this question, and for the calculated effluent release, the current value is a reasonable estimate of a factor that must be included in the calculation.

Filter Burial Factor

$F_B$ is a factor to account for the filter burial of alpha emitters, currently equal to 1.6. This is the value used for Hollingsworth & Vose HV-70 filter paper for air sampling of plutonium stacks in the 1970s. It is not known what type of paper was used for D-Building's air sampling, but the current value is a reasonable estimate of a factor that must be included in the calculation.

Decay Rate Conversion, a constant

$F_{Conv}$ is a factor to convert from decays per minute (dpm) to μCi. The value of this constant is $4.50 \times 10^{-7}$ μCi per dpm.

Hood Factor

$F_{Hood}$ is the ratio of hood air concentration to room air concentration that is usually a design consideration when constructing a hood. It is a measure of the contamination control provided by the hood. In our current calculations, the value used is 300. This factor is discussed further below.

Room Area

$A_{room}$ is the areal footprint of a particular room. This factor and the Room Ceiling Height were multiplied together to yield the room volume. For each room in D Building that had a reported monthly average concentration, the room area was determined from a floor plan drawing for D Building. It could not be determined from the drawing what equipment occupied the room, and so the room volume is missing a term that represents the fraction of the total room volume that is unoccupied. In other words, that fraction has been assumed to be unity.

Room Ceiling Height

$H_{room}$ is the ceiling height of a particular room. This is assumed to be 10 feet. Structural drawings of D Building have been requested to support this assumption.

Air Exchange Rate

$A_{Ex}$ is the air exchange rate for a particular room. Presently, all rooms are assumed to have 10 air exchanges per hour. Lacking actual stack flow rate data for D Building, an estimate of the number of air exchanges per hour was needed for the model. The current value is a reasonable estimate of modern laboratory air exchange requirements. Modern office requirements are less, approximately 6 air exchanges per hour.

The use of the Air Exchange Rate and the room volume is to generate the volumetric flow rate for a room.

Volume Conversion Factor, a constant

$F_{Vol}$ is a conversion factor for room volume, converting from cubic feet to liters. The value of this constant is 28.317 liters per cubic foot.

Working Days per Month

$W_{D/M}$ is the number of working days per month, currently equal to 27. It was assumed, for convenience's sake, that there were 31 days per month, there were four Sundays per month, and that Sunday was not a workday for the laboratory. It is believed that this assumption is not critical to the calculations. Although changes in this term have a proportional effect on the computed release, large changes in its value are not anticipated.

Working Hours per Day

$W$ is the number of working hours per day, currently equal to 10. It was simply assumed that a working day was ten hours long. No documentation has been found to support this, but the reports from DP Site indicate that night operations were sharply curtailed from day operations. It seems reasonable to assume a similar situation for D Building.

Ten hours seems reasonable, and may even be slightly on the low side, considering that during the war months, there was a great deal of work to conduct with an unknown material. Such an environment would naturally have demanded more hours per day. It is believed that this assumption is not critical to the calculations. Although changes in this term have a proportional effect on the computed release, large changes in its value are not anticipated.

In summary, the current values of the parameters are as shown in Table B-1:

**Table B-1. Values of Current D-Building Release Estimation Method Parameters**

| Parameter | Value |
|---|---|
| $F_{Dg}$ | 2.0 (dimensionless) |
| $F_{Di}$ | 1.25 (dimensionless) |
| $F_B$ | 1.6 (dimensionless) |
| $F_{Conv}$ | 4.50E-07 μCi per dpm |
| $F_{Hood}$ | 300 (dimensionless) |
| $H_{Room}$ | 10 feet |
| $A_{Ex}$ | 10 air exchanges per hour |
| $F_{Vol}$ | 28.317 liters per cubic foot |
| $W_{D/M}$ | 27 days per month |
| $W$ | 10 hours per day |

**The Nature of the Method**

A natural question to ask is whether the method would tend to over-estimate or under-estimate the true but unknown source term. In this section, the many considerations that drove the design of the method and the choices of values of the factors are discussed.

The extent of missing data and information lent itself to a method that underestimates the airborne releases. The intent of the approach was to provide a lower-bound estimate. A conservative factor, as used in this discussion, is one that avoids significantly overstating the release.

Conservatisms

Hood Factor

The method begins with room air concentrations, but uses a hood concentration factor to estimate the concentrations inside the hood and dryboxes. Lacking of stack monitoring data but having the room air concentrations, and knowing that there are some design criteria that require certain ratios between hood air concentrations and the air just outside the hood (the breathing zone), this factor was included to represent these requirements. Modern designs for hoods were briefly researched to determine values of this ratio of concentrations. A ratio of 100,000 – 1,000,000 to 1 (hood to breathing zone) was found for modern hood design.

A hood in the 1940s may not meet modern performance requirements. Just as certain, its performance could be no worse than a ratio of 1, i.e. the same concentration inside the hood as outside the hood. The

value of 300 was used to represent this current state of knowledge; it is the approximate geometric mean of the modern value of 100,000 and the no worse value of 1, and as such provides a measure of the spread of the ratios. It lacks an estimate of its uncertainty. There is no data on which to base such an estimate.

A related factor is the breathing zone to laboratory air ratio of air concentrations. It is known from the reports that the filter queens were sometimes placed near a hood, and at other times they were placed away from equipment in more open room space. The monthly reports give sporadic notes about locations. The method includes this factor implicitly as an element of the hood factor.

Effluent Flow Rate

The approach uses an air exchange rate combined with a room volume to estimate an effluent flow rate out of each room; the end result is that the method treats each room as a hood. The method currently assumes that there were 10 air exchanges per hour. This value is based on typical values for laboratory airspaces. Modern office spaces would have a smaller value. There are significant uncertainties in this quantity.

The flow rates out of the hoods and dryboxes are unknown. It is probable that there was more than one hood or drybox in each room, and thus the method may underestimate the effluent flow rate.

The room volumes are the other part of the effluent flow rate estimates. These volumes are simply calculated from the room floor area, determined from a scale drawing of D Building, and an assumed ceiling height of 10 feet.

Missing Data

The room air concentration data begin with December 1945. It is known that significant quantities of plutonium began to arrive in May 1945 (see above). If it is assumed that the arrival of significant quantities implies the release of significant quantities in the airborne effluent, then the lack of room air concentration data in the method for May through November 1945 results in an underestimate of the released activity. It is not know if room air concentrations exist for this time period. They have not been found in the other CM/CMR-12 monthly reports.

Other significant missing data are the lack of room air concentrations for all operating rooms. After reviewing the floor plan of D Building and the CM/CMR-12 monthly reports, it is obvious that not all rooms with operations were routinely monitored. Rooms were only monitored when there was some special concern that a process warranted monitoring, and when there was equipment (Filter Queens) and staff available.

The lack of room air concentrations for all operating rooms causes the method to underestimate the released activity. The approach currently only estimates releases from those rooms with reported concentrations. The estimated effluent activity would certainly increase, by an unknown amount, if all operating rooms were included.

Non-conservatisms

Since the intent of the method is to provide a lower-bound estimate, any terms that would tend to overstate the release would be non-conservative terms.

Exhaust Filters

The CM/CMR-12 monthly reports give some indication that the exhaust ducts from the hoods and dryboxes were filtered with some kind of fabric to capture small particles. The nature and quality of this filter is unknown and is not included in the model. The inclusion of a filter would decrease the estimate of the released activity. The lack of factor to represent these filters in the present approach is a non-conservatism.

Actually, the decrease is dependent upon the particle size distribution of the effluent from the hoods and dryboxes. Large particles would carry large activity, but would tend to either fall out in the hood or drybox or be captured in the filter medium. This was the design purpose of such a filter. Smaller particles would carry less activity, but the filter would be less efficient. Without information on the particle size, this efficiency is cannot be determined.

Effluent Re-entrainment

The method takes no account of the re-entrainment of the effluent air back into the building ventilation air intake. From DP Site records, it is known that re-entrainment was responsible for contaminating the first few rooms downstream of the buildings' air intakes during the early years of DP Site operations. It is not known if this was a factor in D Building operations. If the hood factor is large, then the importance of re-entrainment is great. In this case, room air concentrations for some rooms downstream of the air supply plenum would have larger air concentrations than the hoods or dryboxes would normally create.

For the more modest hood factor currently assumed, re-entrainment is less important, as the effluent air has a lower concentration due to the much smaller hood factor.

Indeterminate conservatisms

These aspects of the release estimation approach have an unknown conservatism. Without further study and more information, these factors could be revised to either decrease or increase in value.

Working Days per Month

The method currently uses 27 working days. It is certainly possible that either more or less days were worked. An increase or decrease in the value has a concomitant effect on the amount of effluent activity.

No log of the work schedule has been found. This would be the best information to have to correctly estimate this value.

Hours per Work Day

The model currently uses 10 working hours. No information has been found to support this value. It might be an underestimation during the war months, when there was an overriding urgency, and it might be an overestimation in the post-war years, when it might be expected that the work was slightly less urgent.

Burial Factor

The current value of the burial factor is 1.6. This is the value for the HV-70 filter paper. It is not known what filter paper was used with the filter queens in D Building, so it is possible that the burial factor could be greater or less than the present value.

Detector Geometry

It is not known if the 2p correction was applied to the room air concentration measurements. The method currently assumes that it was not, and uses a factor of 2.0 to correct the activity.

Intrinsic Efficiency

Since the detector used to count the filter papers is presently unknown, the intrinsic efficiency most likely is different from the current value of 0.8. If the number is revised to a smaller value, the corresponding factor increases, which would yield an increase in estimated effluent activity.

Particle Size Distribution

As discussed earlier in this appendix, the distribution of particle sizes determines the efficiency of the filters on the exhausts of the hoods and dryboxes. If the distribution were dominated by large particle sizes, the filters would have removed such large activity carrying particles. If the distribution were dominated by smaller particle sizes, one would expect poorer performance from the filters. The measure of that performance, the efficiency, is an unknown quantity but is dependent on the particle size distribution.

# APPENDIX C: SAMPLES OF AVAILABLE ENVIRONMENTAL MEASUREMENTS

# Table C-1: Selected Surface Water Samples from Los Alamos Canyon and Other Areas of Interest

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| Surface Water | plutonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 210 | dpm/L | East end of TA Laundry drainage |
| Surface Water | plutonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 2100 | dpm/L | East end of TA Laundry drainage |
| Surface Water | plutonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 130 | dpm/L | West end of TA Laundry Drainage |
| Surface Water | plutonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 13000 | dpm/L | West end of TA Laundry Drainage |
| Surface Water | plutonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 7120 | dpm/L | Laundry water in nearby ditches |
| Surface Water | plutonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 5000 | dpm/L | Laundry water in nearby ditches |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 1300 | dpm/L | Immediately below Laundry |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 3100 | dpm/L | Immediately below Laundry |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 520 | dpm/L | 100 yds downstream from Laundry |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 200 | dpm/L | 200 yds downstream from Laundry |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 80 | dpm/L | 300 yds downstream from Laundry |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 0 | dpm/L | Beside Omega Site |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 84 | dpm/L | Southwest of Technical Area |
| Surface Water | plutonium | 1945 | Los Alamos Canyon | Tribby, 1945/ CDC Rep # 230 | 1 | 144000 | dpm/L | Near Laundry ditch |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 62000 | dpm/L | Near Laundry ditch |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 0 | dpm/L | Beside DP site |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 12 | dpm/L | Beside DP site |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 12 | dpm/L | Near Loudermilk |
| Surface Water | plutonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 16 | dpm/L | Near Rio Grande |
| Surface Water | Pu-238 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 1.4 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | Pu-238 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.14 | pCi/L | approx. 1 mi. downstream of outfall |
| Surface Water | Pu-239 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 1.9 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | Pu-239 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.22 | pCi/L | approx. 1 mi. downstream of outfall |
| | | | | | | | | |
| Surface Water | polonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 4200 | dpm/L | East end of TA Laundry drainage |
| Surface Water | polonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 77000 | dpm/L | East end of TA Laundry drainage |
| Surface Water | polonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 59000 | dpm/L | West end of TA Laundry Drainage |
| Surface Water | polonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 200000 | dpm/L | West end of TA Laundry Drainage |
| Surface Water | polonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 370000 | dpm/L | Laundry water in nearby ditches |
| Surface Water | polonium | 1945 | Drainage ditch to Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 820000 | dpm/L | Laundry water in nearby ditches |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 12000 | dpm/L | Immediately below Laundry |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 19000 | dpm/L | Immediately below Laundry |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 280 | dpm/L | 100 yds downstream from Laundry |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 620 | dpm/L | 200 yds downstream from Laundry |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 1860 | dpm/L | 300 yds downstream from Laundry |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 48 | dpm/L | Beside Omega Site |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 2300 | dpm/L | Southwest of Technical Area |
| Surface Water | polonium | 1945 | Los Alamos Canyon | Tribby, 1945/ CDC Rep # 230 | 1 | 48000 | dpm/L | Near Laundry ditch |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 114000 | dpm/L | Near Laundry ditch |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 0 | dpm/L | Beside DP site |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 4 | dpm/L | Beside DP site |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 16 | dpm/L | Near Loudermilk |
| Surface Water | polonium | 1945 | Los Alamos Creek | Tribby, 1945/ CDC Rep # 230 | 1 | 0 | dpm/L | Near Rio Grande |
| Surface Water | Am-241 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.46 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | Am-241 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.07 | pCi/L | approx. 1 mi. downstream of outfall |

## Table C-1: Selected Surface Water Samples from Los Alamos Canyon and Other Areas of Interest

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Surface Water | U-234 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.18 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | U-234 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.01 | pCi/L | approx. 1 mi. downstream of outfall |
| | | | | | | | | |
| Surface Water | tritium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 550,000 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | tritium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 100,000 | pCi/L | approx. 1 mi. downstream of outfall |
| | | | | | | | | |
| Surface Water | Cs-137 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 800 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | Cs-137 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | <400 | pCi/L | approx. 1 mi. downstream of outfall |
| Surface Water | Sr-90 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 920 | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | Sr-90 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 310 | pCi/L | approx. 1 mi. downstream of outfall |
| Surface Water | total uranium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 23 | µg/ml | approx. 0.5 mi. downstream of outfall |
| Surface Water | total uranium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 6 | µg/ml | approx. 1 mi. downstream of outfall |
| Surface Water | chromium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 3 | µg/ml | approx. 0.5 mi. downstream of outfall |
| Surface Water | chromium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 2 | µg/ml | approx. 1 mi. downstream of outfall |
| Surface Water | cadmium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.12 | µg/ml | approx. 0.5 mi. downstream of outfall |
| Surface Water | cadmium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 0.0072 | µg/ml | approx. 1 mi. downstream of outfall |
| Surface Water | mercury | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | 9 | µg/ml | approx. 0.5 mi. downstream of outfall |
| Surface Water | mercury | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | <2 | µg/ml | approx. 1 mi. downstream of outfall |
| Surface Water | | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | | pCi/L | approx. 1 mi. downstream of outfall |
| Surface Water | | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | | pCi/L | approx. 0.5 mi. downstream of outfall |
| Surface Water | | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | | pCi/L | approx. 1 mi. downstream of outfall |
| Surface Water | | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | NA | | pCi/L | approx. 0.5 mi. downstream of outfall |
| | | | | | | | | approx. 1 mi. downstream of outfall |

## Table C-2: Selected Soil and Sediment Samples from Los Alamos Canyon

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep #s | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| soil | gross alpha | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 8000 | pCi/g | sample near TA-21 |
| sediment | gross alpha | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 18000 | pCi/g | sample near TA-21 |
| sediment | gross alpha | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | <1000 | pCi/g | sample near TA-21 |
| soil | gross beta | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 7000 | pCi/g | sample near TA-21 |
| sediment | gross beta | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 73000 | pCi/g | sample near TA-21 |
| sediment | gross beta | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | <1000 | pCi/g | sample near TA-21 |
| soil | Pu-238 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 26 | pCi/g | sample near TA-21 |
| sediment | Pu-238 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 2500 | pCi/g | sample near TA-21 |
| sediment | Pu-238 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 3 | pCi/g | sample near TA-21 |
| soil | Pu-239 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 14 | pCi/g | sample near TA-21 |
| sediment | Pu-239 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 1400 | pCi/g | sample near TA-21 |
| sediment | Pu-239 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 53 | pCi/g | sample near TA-21 |
| soil | tritium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 270,000 | pCi/L | soil moisture content/sample near TA-21 |
| sediment | tritium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | NA | pCi/L | soil moisture content/sample near TA-21 |
| soil | Cs-137 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 300 | pCi/g | sample near TA-21 |
| sediment | Cs-137 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 10000 | pCi/g | sample near TA-21 |
| sediment | Cs-137 | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 300 | pCi/g | sample near TA-21 |
| soil | total uranium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 0.39 | µg/g | sample near TA-21 |
| sediment | total uranium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 0.16 | µg/g | sample near TA-21 |
| sediment | total uranium | 1971 | Los Alamos Canyon | LASL, 1972b/CDC Rep # | 1 | 0.02 | µg/g | sample near TA-21 |

# Table C-3: Selected Off-site Air Monitoring Results

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Max | Mean | Units | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Air | gross alpha | 1971 | Diamond Drive | LASL, 1972b/CDC Rep # | 24 | 7.3 | 1.3 | fCi m-3 | off-site monitoring station 1 |
| Air | gross alpha | 1971 | High School | LASL, 1972b/CDC Rep # | 2 | 1.4 | 1.0 | fCi m-3 | off-site monitoring station 2 |
| Air | gross alpha | 1971 | Mountain School | LASL, 1972b/CDC Rep # | 13 | 7 | 1.4 | fCi m-3 | off-site monitoring station 3 |
| Air | gross alpha | 1971 | Pueblo Junior High School | LASL, 1972b/CDC Rep # | 2 | 1.7 | 1.2 | fCi m-3 | off-site monitoring station 4 |
| Air | gross alpha | 1971 | Arkansas Avenue | LASL, 1972b/CDC Rep # | 14 | 1.2 | 0.6 | fCi m-3 | off-site monitoring station 5 |
| Air | arito Acres | 1971 | Little Forest School | LASL, 1972b/CDC Rep # | 2 | 1.7 | 1.6 | fCi m-3 | off-site monitoring station 6 |
| Air | gross alpha | 1971 | Aspen School | LASL, 1972b/CDC Rep # | 2 | 2.1 | 1.7 | fCi m-3 | off-site monitoring station 7 |
| Air | gross alpha | 1971 | Pajarito School | LASL, 1972b/CDC Rep # | 13 | 5 | 1.3 | fCi m-3 | off-site monitoring station 8 |
| Air | gross alpha | 1971 | Golf Course | LASL, 1972b/CDC Rep # | 24 | 5.2 | 1.0 | fCi m-3 | off-site monitoring station 9 |
| Air | gross alpha | 1971 | Museum | LASL, 1972b/CDC Rep # | 27 | 9.4 | 1.1 | fCi m-3 | off-site monitoring station 10 |
| Air | gross alpha | 1971 | Cumbres Junior High School | LASL, 1972b/CDC Rep # | 27 | 5.2 | 1.1 | fCi m-3 | off-site monitoring station 11 |
| Air | gross alpha | 1971 | Acorn Street | LASL, 1972b/CDC Rep # | 27 | 10 | 1.1 | fCi m-3 | off-site monitoring station 12 |
| Air | gross alpha | 1971 | Canyon School | LASL, 1972b/CDC Rep # | 2 | 2.3 | 1.9 | fCi m-3 | off-site monitoring station 13 |
| Air | gross alpha | 1971 | Barranca School | LASL, 1972b/CDC Rep # | 27 | 3.5 | 1.1 | fCi m-3 | off-site monitoring station 14 |
| Air | gross alpha | 1971 | Guaje Booster 2 | LASL, 1972b/CDC Rep # | 27 | 8.5 | 1.2 | fCi m-3 | off-site monitoring station 15 |
| Air | gross alpha | 1971 | Airport | LASL, 1972b/CDC Rep # | 27 | 9.1 | 1.2 | fCi m-3 | off-site monitoring station 16 |
| Air | gross alpha | 1971 | Guaje Booster 1 | LASL, 1972b/CDC Rep # | 27 | 5.5 | 1.1 | fCi m-3 | off-site monitoring station 17 |
| Air | gross alpha | 1971 | Espanola | LASL, 1972b/CDC Rep # | 27 | 6.9 | 1.4 | fCi m-3 | off-site monitoring station 18 |
| Air | gross alpha | 1971 | Bayo STP | LASL, 1972b/CDC Rep # | 16 | 31 | 2.6 | fCi m-3 | off-site monitoring station 19 |
| Air | gross alpha | 1971 | Well G-1 | LASL, 1972b/CDC Rep # | 27 | 5.7 | 1.1 | fCi m-3 | off-site monitoring station 20 |
| Air | gross alpha | 1971 | Well LA-3 | LASL, 1972b/CDC Rep # | 27 | 1.9 | 0.7 | fCi m-3 | off-site monitoring station 21 |
| Air | gross alpha | 1971 | White Rock STP | LASL, 1972b/CDC Rep # | 14 | 2 | 0.7 | fCi m-3 | off-site monitoring station 22 |
| Air | gross alpha | 1971 | Pinon School | LASL, 1972b/CDC Rep # | 13 | 5.9 | 1.5 | fCi m-3 | off-site monitoring station 23 |
| Air | gross alpha | 1971 | Santa Fe | LASL, 1972b/CDC Rep # | 25 | 4 | 1.6 | fCi m-3 | off-site monitoring station 24 |
| Air | gross alpha | 1971 | Pajarito Acres | LASL, 1972b/CDC Rep # | 27 | 6 | 1.1 | fCi m-3 | off-site monitoring station 25 |
| Air | gross alpha | 1971 | Bandelier entrance | LASL, 1972b/CDC Rep # | 8 | 0.9 | 0.3 | fCi m-3 | off-site monitoring station 26 |
| Air | gross alpha | 1971 | Bandelier HQ | LASL, 1972b/CDC Rep # | 8 | 2.9 | 0.6 | fCi m-3 | off-site monitoring station 27 |
| Air | gross alpha | 1972 | Diamond Drive | LASL, 1973/CDC Rep # 887 | NA | 4.2 | 1.6 | fCi m-3 | off-site monitoring station 1 |
| Air | gross alpha | 1972 | Arkansas Avenue | LASL, 1973/CDC Rep # 887 | NA | 3.6 | 1.6 | fCi m-3 | off-site monitoring station 2 |
| Air | gross alpha | 1972 | Golf Course | LASL, 1973/CDC Rep # 887 | NA | 4.6 | 1.5 | fCi m-3 | off-site monitoring station 3 |
| Air | gross alpha | 1972 | Fuller Lodge | LASL, 1973/CDC Rep # 887 | NA | 4.7 | 1.6 | fCi m-3 | off-site monitoring station 4 |
| Air | gross alpha | 1972 | Cumbres Junior High School | LASL, 1973/CDC Rep # 887 | NA | 4.5 | 1.7 | fCi m-3 | off-site monitoring station 5 |
| Air | gross alpha | 1972 | Acorn Street | LASL, 1973/CDC Rep # 887 | NA | 6 | 1.4 | fCi m-3 | off-site monitoring station 6 |
| Air | gross alpha | 1972 | Barranca School | LASL, 1973/CDC Rep # 887 | NA | 3.6 | 1.6 | fCi m-3 | off-site monitoring station 7 |
| Air | gross alpha | 1972 | Guaje Booster 2 | LASL, 1973/CDC Rep # 887 | NA | 4.8 | 2.0 | fCi m-3 | off-site monitoring station 8 |
| Air | gross alpha | 1972 | Airport | LASL, 1973/CDC Rep # 887 | NA | 6.4 | 1.9 | fCi m-3 | off-site monitoring station 9 |
| Air | gross alpha | 1972 | Guaje Booster 1 | LASL, 1973/CDC Rep # 887 | NA | 4.6 | 1.9 | fCi m-3 | off-site monitoring station 10 |
| Air | gross alpha | 1972 | Espanola | LASL, 1973/CDC Rep # 887 | NA | 6.2 | 2.1 | fCi m-3 | off-site monitoring station 11 |
| Air | gross alpha | 1972 | Bayo STP | LASL, 1973/CDC Rep # 887 | NA | 7.6 | 1.6 | fCi m-3 | off-site monitoring station 12 |
| Air | gross alpha | 1972 | Well G-1 | LASL, 1973/CDC Rep # 887 | NA | 4.7 | 1.7 | fCi m-3 | off-site monitoring station 13 |
| Air | gross alpha | 1972 | Well LA-3 | LASL, 1973/CDC Rep # 887 | NA | 3.7 | 1.7 | fCi m-3 | off-site monitoring station 14 |

# Table C-3: Selected Off-site Air Monitoring Results

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Max | Mean | Units | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Air | gross alpha | 1972 | White Rock STP | LASL, 1973/CDC Rep # 887 | NA | 4.3 | 1.6 | fCi m-3 | off-site monitoring station 15 |
| Air | gross alpha | 1972 | Santa Fe | LASL, 1973/CDC Rep # 887 | NA | 7.2 | 2.0 | fCi m-3 | off-site monitoring station 16 |
| Air | gross alpha | 1972 | Pajarito Acres | LASL, 1973/CDC Rep # 887 | NA | 4.2 | 1.3 | fCi m-3 | off-site monitoring station 17 |
| Air | gross alpha | 1972 | Bandelier lookout | LASL, 1973/CDC Rep # 887 | NA | 4.5 | 1.4 | fCi m-3 | off-site monitoring station 18 |
| Air | gross alpha | 1972 | Bandelier HQ | LASL, 1973/CDC Rep # 887 | NA | 4.4 | 1.5 | fCi m-3 | off-site monitoring station 19 |
| | | | | | | | | | |
| Air | gross beta | 1972 | Diamond Drive | LASL, 1973/CDC Rep # 887 | NA | 1680 | 190.0 | fCi m-3 | off-site monitoring station 1 |
| Air | gross beta | 1972 | Arkansas Avenue | LASL, 1973/CDC Rep # 887 | NA | 2190 | 180.0 | fCi m-3 | off-site monitoring station 2 |
| Air | gross beta | 1972 | Golf Course | LASL, 1973/CDC Rep # 887 | NA | 1550 | 200.0 | fCi m-3 | off-site monitoring station 3 |
| Air | gross beta | 1972 | Fuller Lodge | LASL, 1973/CDC Rep # 887 | NA | 2440 | 190.0 | fCi m-3 | off-site monitoring station 4 |
| Air | gross beta | 1972 | Cumbres Junior High School | LASL, 1973/CDC Rep # 887 | NA | 1830 | 190.0 | fCi m-3 | off-site monitoring station 5 |
| Air | gross beta | 1972 | Acorn Street | LASL, 1973/CDC Rep # 887 | NA | 2200 | 200.0 | fCi m-3 | off-site monitoring station 6 |
| Air | gross beta | 1972 | Barranca School | LASL, 1973/CDC Rep # 887 | NA | 1990 | 190.0 | fCi m-3 | off-site monitoring station 7 |
| Air | gross beta | 1972 | Guaje Booster 2 | LASL, 1973/CDC Rep # 887 | NA | 2600 | 180.0 | fCi m-3 | off-site monitoring station 8 |
| Air | gross beta | 1972 | Airport | LASL, 1973/CDC Rep # 887 | NA | 1950 | 200.0 | fCi m-3 | off-site monitoring station 9 |
| Air | gross beta | 1972 | Guaje Booster 1 | LASL, 1973/CDC Rep # 887 | NA | 3190 | 200.0 | fCi m-3 | off-site monitoring station 10 |
| Air | gross beta | 1972 | Espanola | LASL, 1973/CDC Rep # 887 | NA | 2570 | 190.0 | fCi m-3 | off-site monitoring station 11 |
| Air | gross beta | 1972 | Bayo STP | LASL, 1973/CDC Rep # 887 | NA | 1650 | 190.0 | fCi m-3 | off-site monitoring station 12 |
| Air | gross beta | 1972 | Well G-1 | LASL, 1973/CDC Rep # 887 | NA | 2940 | 190.0 | fCi m-3 | off-site monitoring station 13 |
| Air | gross beta | 1972 | Well LA-3 | LASL, 1973/CDC Rep # 887 | NA | 1590 | 220.0 | fCi m-3 | off-site monitoring station 14 |
| Air | gross beta | 1972 | White Rock STP | LASL, 1973/CDC Rep # 887 | NA | 1640 | 180.0 | fCi m-3 | off-site monitoring station 15 |
| Air | gross beta | 1972 | Santa Fe | LASL, 1973/CDC Rep # 887 | NA | 1920 | 180.0 | fCi m-3 | off-site monitoring station 16 |
| Air | gross beta | 1972 | Pajarito Acres | LASL, 1973/CDC Rep # 887 | NA | 1900 | 190.0 | fCi m-3 | off-site monitoring station 17 |
| Air | gross beta | 1972 | Bandelier lookout | LASL, 1973/CDC Rep # 887 | NA | 2190 | 180.0 | fCi m-3 | off-site monitoring station 18 |
| Air | gross beta | 1972 | Bandelier HQ | LASL, 1973/CDC Rep # 887 | NA | 3270 | 180.0 | fCi m-3 | off-site monitoring station 19 |
| | | | | | | | | | |
| Air | Pu-238 | 1972 | Diamond Drive | LASL, 1973/CDC Rep # 887 | NA | 0.034 | 0.017 | fCi m-3 | off-site monitoring station 1 |
| Air | Pu-238 | 1972 | Arkansas Avenue | LASL, 1973/CDC Rep # 887 | NA | 0.194 | 0.032 | fCi m-3 | off-site monitoring station 2 |
| Air | Pu-238 | 1972 | Golf Course | LASL, 1973/CDC Rep # 887 | NA | 0.350 | 0.041 | fCi m-3 | off-site monitoring station 3 |
| Air | Pu-238 | 1972 | Fuller Lodge | LASL, 1973/CDC Rep # 887 | NA | 0.117 | 0.031 | fCi m-3 | off-site monitoring station 4 |
| Air | Pu-238 | 1972 | Cumbres Junior High School | LASL, 1973/CDC Rep # 887 | NA | 0.070 | 0.024 | fCi m-3 | off-site monitoring station 5 |
| Air | Pu-238 | 1972 | Acorn Street | LASL, 1973/CDC Rep # 887 | NA | 0.033 | 0.014 | fCi m-3 | off-site monitoring station 6 |
| Air | Pu-238 | 1972 | Barranca School | LASL, 1973/CDC Rep # 887 | NA | 0.037 | 0.015 | fCi m-3 | off-site monitoring station 7 |
| Air | Pu-238 | 1972 | Guaje Booster 2 | LASL, 1973/CDC Rep # 887 | NA | 0.073 | 0.019 | fCi m-3 | off-site monitoring station 8 |
| Air | Pu-238 | 1972 | Airport | LASL, 1973/CDC Rep # 887 | NA | 0.209 | 0.028 | fCi m-3 | off-site monitoring station 9 |
| Air | Pu-238 | 1972 | Guaje Booster 1 | LASL, 1973/CDC Rep # 887 | NA | 0.068 | 0.025 | fCi m-3 | off-site monitoring station 10 |
| Air | Pu-238 | 1972 | Espanola | LASL, 1973/CDC Rep # 887 | NA | 0.019 | 0.014 | fCi m-3 | off-site monitoring station 11 |
| Air | Pu-238 | 1972 | Bayo STP | LASL, 1973/CDC Rep # 887 | NA | 0.136 | 0.029 | fCi m-3 | off-site monitoring station 12 |
| Air | Pu-238 | 1972 | Well G-1 | LASL, 1973/CDC Rep # 887 | NA | 0.031 | 0.016 | fCi m-3 | off-site monitoring station 13 |
| Air | Pu-238 | 1972 | Well LA-3 | LASL, 1973/CDC Rep # 887 | NA | 0.046 | 0.019 | fCi m-3 | off-site monitoring station 14 |
| Air | Pu-238 | 1972 | White Rock STP | LASL, 1973/CDC Rep # 887 | NA | 0.099 | 0.022 | fCi m-3 | off-site monitoring station 15 |

# Table C-3: Selected Off-site Air Monitoring Results

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Max | Mean | Units | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Air | Pu-238 | 1972 | Santa Fe | LASL, 1973/CDC Rep # 887 | NA | 0.026 | 0.014 | fCi m-3 | off-site monitoring station 16 |
| Air | Pu-238 | 1972 | Pajarito Acres | LASL, 1973/CDC Rep # 887 | NA | 0.048 | 0.019 | fCi m-3 | off-site monitoring station 17 |
| Air | Pu-238 | 1972 | Bandelier lookout | LASL, 1973/CDC Rep # 887 | NA | 0.059 | 0.017 | fCi m-3 | off-site monitoring station 18 |
| Air | Pu-238 | 1972 | Bandelier HQ | LASL, 1973/CDC Rep # 887 | NA | 0.036 | 0.016 | fCi m-3 | off-site monitoring station 19 |
| | | | | | | | | | |
| Air | Pu-239 | 1972 | Diamond Drive | LASL, 1973/CDC Rep # 887 | NA | 0.363 | 0.069 | fCi m-3 | off-site monitoring station 1 |
| Air | Pu-239 | 1972 | Arkansas Avenue | LASL, 1973/CDC Rep # 887 | NA | 0.160 | 0.047 | fCi m-3 | off-site monitoring station 2 |
| Air | Pu-239 | 1972 | Golf Course | LASL, 1973/CDC Rep # 887 | NA | 0.117 | 0.040 | fCi m-3 | off-site monitoring station 3 |
| Air | Pu-239 | 1972 | Fuller Lodge | LASL, 1973/CDC Rep # 887 | NA | 0.104 | 0.043 | fCi m-3 | off-site monitoring station 4 |
| Air | Pu-239 | 1972 | Cumbres Junior High School | LASL, 1973/CDC Rep # 887 | NA | 0.191 | 0.050 | fCi m-3 | off-site monitoring station 5 |
| Air | Pu-239 | 1972 | Acorn Street | LASL, 1973/CDC Rep # 887 | NA | 0.108 | 0.035 | fCi m-3 | off-site monitoring station 6 |
| Air | Pu-239 | 1972 | Barranca School | LASL, 1973/CDC Rep # 887 | NA | 0.148 | 0.046 | fCi m-3 | off-site monitoring station 7 |
| Air | Pu-239 | 1972 | Guaje Booster 2 | LASL, 1973/CDC Rep # 887 | NA | 0.087 | 0.036 | fCi m-3 | off-site monitoring station 8 |
| Air | Pu-239 | 1972 | Airport | LASL, 1973/CDC Rep # 887 | NA | 0.265 | 0.073 | fCi m-3 | off-site monitoring station 9 |
| Air | Pu-239 | 1972 | Guaje Booster 1 | LASL, 1973/CDC Rep # 887 | NA | 0.197 | 0.047 | fCi m-3 | off-site monitoring station 10 |
| Air | Pu-239 | 1972 | Espanola | LASL, 1973/CDC Rep # 887 | NA | 0.108 | 0.038 | fCi m-3 | off-site monitoring station 11 |
| Air | Pu-239 | 1972 | Bayo STP | LASL, 1973/CDC Rep # 887 | NA | 0.122 | 0.037 | fCi m-3 | off-site monitoring station 12 |
| Air | Pu-239 | 1972 | Well G-1 | LASL, 1973/CDC Rep # 887 | NA | 0.126 | 0.047 | fCi m-3 | off-site monitoring station 13 |
| Air | Pu-239 | 1972 | Well LA-3 | LASL, 1973/CDC Rep # 887 | NA | 0.089 | 0.041 | fCi m-3 | off-site monitoring station 14 |
| Air | Pu-239 | 1972 | White Rock STP | LASL, 1973/CDC Rep # 887 | NA | 0.186 | 0.061 | fCi m-3 | off-site monitoring station 15 |
| Air | Pu-239 | 1972 | Santa Fe | LASL, 1973/CDC Rep # 887 | NA | 0.073 | 0.033 | fCi m-3 | off-site monitoring station 16 |
| Air | Pu-239 | 1972 | Pajarito Acres | LASL, 1973/CDC Rep # 887 | NA | 0.105 | 0.038 | fCi m-3 | off-site monitoring station 17 |
| Air | Pu-239 | 1972 | Bandelier lookout | LASL, 1973/CDC Rep # 887 | NA | 0.144 | 0.031 | fCi m-3 | off-site monitoring station 18 |
| Air | Pu-239 | 1972 | Bandelier HQ | LASL, 1973/CDC Rep # 887 | NA | 0.101 | 0.028 | fCi m-3 | off-site monitoring station 19 |

# Table C-4: Selected On-Site Air Monitoring Results

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Max | Mean | Units | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Air | gross alpha | 1971 | Ta-21 | LASL, 1972b/CDC Rep # | 17 | 1.5 | 1 | fCi m-3 | on-site air monitoring station 28 |
| Air | gross alpha | 1971 | TA-53 | LASL, 1972b/CDC Rep # | 9 | 14 | 2 | fCi m-3 | on-site air monitoring station 29 |
| Air | gross alpha | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 10 | 5.4 | 2 | fCi m-3 | on-site air monitoring station 30 |
| Air | gross alpha | 1971 | East Jemez Road | LASL, 1972b/CDC Rep # | 17 | 1.1 | 1 | fCi m-3 | on-site air monitoring station 31 |
| Air | gross alpha | 1971 | Beta Site | LASL, 1972b/CDC Rep # | 8 | 1 | 0 | fCi m-3 | on-site air monitoring station 32 |
| Air | arito Acres | 1971 | Pajarito Booster 2 | LASL, 1972b/CDC Rep # | 17 | 2 | 1 | fCi m-3 | on-site air monitoring station 33 |
| Air | gross alpha | 1971 | Pajarito Booster 1 | LASL, 1972b/CDC Rep # | 17 | 1.4 | 1 | fCi m-3 | on-site air monitoring station 34 |
| Air | gross alpha | 1971 | TA-36 | LASL, 1972b/CDC Rep # | 18 | 2.3 | 1 | fCi m-3 | on-site air monitoring station 35 |
| Air | gross alpha | 1971 | TA-33 | LASL, 1972b/CDC Rep # | 27 | 3.2 | 1 | fCi m-3 | on-site air monitoring station 36 |
| Air | gross alpha | 1971 | TA-15 | LASL, 1972b/CDC Rep # | 16 | 1.5 | 1 | fCi m-3 | on-site air monitoring station 37 |
| Air | gross alpha | 1971 | TA-49 | LASL, 1972b/CDC Rep # | 27 | 5.2 | 1 | fCi m-3 | on-site air monitoring station 38 |
| Air | gross alpha | 1971 | TA-11 | LASL, 1972b/CDC Rep # | 16 | 55.1 | 1 | fCi m-3 | on-site air monitoring station 39 |
| Air | gross alpha | 1971 | West Jemez Road | LASL, 1972b/CDC Rep # | 15 | 2.1 | 1 | fCi m-3 | on-site air monitoring station 40 |
| Air | gross alpha | 1971 | TA-16 | LASL, 1972b/CDC Rep # | 16 | 1.4 | 1 | fCi m-3 | on-site air monitoring station 41 |
| Air | gross alpha | 1971 | TA-16 (discontinued) | LASL, 1972b/CDC Rep # | 12 | 3.4 | 1 | fCi m-3 | on-site air monitoring station 42 |
| Air | gross alpha | 1971 | TA-6 | LASL, 1972b/CDC Rep # | 8 | 0.9 | 0 | fCi m-3 | on-site air monitoring station 43 |
| Air | gross alpha | 1971 | TA-3 | LASL, 1972b/CDC Rep # | 27 | 11 | 2 | fCi m-3 | on-site air monitoring station 44 |
| Air | gross alpha | 1971 | TA-43 | LASL, 1972b/CDC Rep # | 27 | 8.1 | 1 | fCi m-3 | on-site air monitoring station 45 |
| Air | gross alpha | 1972 | Ta-21 | LASL, 1973/CDC Rep #887 | NA | 2.8 | 1 | fCi m-3 | on-site air monitoring station 20 |
| Air | gross alpha | 1972 | TA-53 | LASL, 1973/CDC Rep #887 | NA | 7.5 | 2 | fCi m-3 | on-site air monitoring station 21 |
| Air | gross alpha | 1972 | Well PM-1 | LASL, 1973/CDC Rep #887 | NA | 5.3 | 2 | fCi m-3 | on-site air monitoring station 22 |
| Air | gross alpha | 1972 | Beta Site | LASL, 1973/CDC Rep #887 | NA | 9.5 | 2 | fCi m-3 | on-site air monitoring station 23 |
| Air | gross alpha | 1972 | Pajarito Booster 2 | LASL, 1973/CDC Rep #887 | NA | 4 | 2 | fCi m-3 | on-site air monitoring station 24 |
| Air | gross alpha | 1972 | Pajarito Booster 1 | LASL, 1973/CDC Rep #887 | NA | 4.5 | 2 | fCi m-3 | on-site air monitoring station 25 |
| Air | gross alpha | 1972 | TA-36 | LASL, 1973/CDC Rep #887 | NA | 3.5 | 1 | fCi m-3 | on-site air monitoring station 26 |
| Air | gross alpha | 1972 | TA-33 | LASL, 1973/CDC Rep #887 | NA | 9.8 | 2 | fCi m-3 | on-site air monitoring station 27 |
| Air | gross alpha | 1972 | TA-15 | LASL, 1973/CDC Rep #887 | NA | 3.5 | 1 | fCi m-3 | on-site air monitoring station 28 |
| Air | gross alpha | 1972 | TA-49 | LASL, 1973/CDC Rep #887 | NA | 4.4 | 2 | fCi m-3 | on-site air monitoring station 29 |
| Air | gross alpha | 1972 | TA-11 | LASL, 1973/CDC Rep #887 | NA | 3.7 | 1 | fCi m-3 | on-site air monitoring station 30 |
| Air | gross alpha | 1972 | West Jemez Road | LASL, 1973/CDC Rep #887 | NA | 4.7 | 2 | fCi m-3 | on-site air monitoring station 31 |
| Air | gross alpha | 1972 | TA-16 | LASL, 1973/CDC Rep #887 | NA | 3.4 | 1 | fCi m-3 | on-site air monitoring station 32 |
| Air | gross alpha | 1972 | TA-6 | LASL, 1973/CDC Rep #887 | NA | 5.2 | 2 | fCi m-3 | on-site air monitoring station 33 |
| Air | gross alpha | 1972 | TA-3 | LASL, 1973/CDC Rep #887 | NA | 4 | 2 | fCi m-3 | on-site air monitoring station 34 |
| Air | gross alpha | 1972 | TA-43 | LASL, 1973/CDC Rep #887 | NA | 5.3 | 2 | fCi m-3 | on-site air monitoring station 35 |
| | | | | | | | | | |
| Air | gross beta | 1972 | Ta-21 | LASL, 1973/CDC Rep #887 | NA | 1410 | 170 | fCi m-3 | on-site air monitoring station 20 |
| Air | gross beta | 1972 | TA-53 | LASL, 1973/CDC Rep #887 | NA | 1860 | 190 | fCi m-3 | on-site air monitoring station 21 |
| Air | gross beta | 1972 | Well PM-1 | LASL, 1973/CDC Rep #887 | NA | 1760 | 180 | fCi m-3 | on-site air monitoring station 22 |
| Air | gross beta | 1972 | Beta Site | LASL, 1973/CDC Rep #887 | NA | 1870 | 200 | fCi m-3 | on-site air monitoring station 23 |
| Air | gross beta | 1972 | Pajarito Booster 2 | LASL, 1973/CDC Rep #887 | NA | 2030 | 200 | fCi m-3 | on-site air monitoring station 24 |
| Air | gross beta | 1972 | Pajarito Booster 1 | LASL, 1973/CDC Rep #887 | NA | 1770 | 180 | fCi m-3 | on-site air monitoring station 25 |
| Air | gross beta | 1972 | TA-36 | LASL, 1973/CDC Rep #887 | NA | 2030 | 170 | fCi m-3 | on-site air monitoring station 26 |
| Air | gross beta | 1972 | TA-33 | LASL, 1973/CDC Rep #887 | NA | 3270 | 210 | fCi m-3 | on-site air monitoring station 27 |
| Air | gross beta | 1972 | TA-15 | LASL, 1973/CDC Rep #887 | NA | 2140 | 200 | fCi m-3 | on-site air monitoring station 28 |
| Air | gross beta | 1972 | TA-49 | LASL, 1973/CDC Rep #887 | NA | 2320 | 190 | fCi m-3 | on-site air monitoring station 29 |
| Air | gross beta | 1972 | TA-11 | LASL, 1973/CDC Rep #887 | NA | 2080 | 180 | fCi m-3 | on-site air monitoring station 30 |
| Air | gross beta | 1972 | West Jemez Road | LASL, 1973/CDC Rep #887 | NA | 2270 | 190 | fCi m-3 | on-site air monitoring station 31 |
| Air | gross beta | 1972 | TA-16 | LASL, 1973/CDC Rep #887 | NA | 1760 | 180 | fCi m-3 | on-site air monitoring station 32 |

# Table C-4: Selected On-Site Air Monitoring Results

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Max | Mean | Units | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Air | gross beta | 1972 | TA-6 | LASL, 1973/CDC Rep #887 | NA | 2150 | 200 | fCi m-3 | on-site air monitoring station 33 |
| Air | gross beta | 1972 | TA-3 | LASL, 1973/CDC Rep #887 | NA | 1940 | 170 | fCi m-3 | on-site air monitoring station 34 |
| Air | gross beta | 1972 | TA-43 | LASL, 1973/CDC Rep #887 | NA | 2140 | 180 | fCi m-3 | on-site air monitoring station 35 |
| | | | | | | | | | |
| Air | Pu-238 | 1972 | Ta-21 | LASL, 1973/CDC Rep #887 | NA | 0.176 | 0.031 | fCi m-3 | on-site air monitoring station 20 |
| Air | Pu-238 | 1972 | TA-53 | LASL, 1973/CDC Rep #887 | NA | 0.053 | 0.031 | fCi m-3 | on-site air monitoring station 21 |
| Air | Pu-238 | 1972 | Well PM-1 | LASL, 1973/CDC Rep #887 | NA | 0.042 | 0.017 | fCi m-3 | on-site air monitoring station 22 |
| Air | Pu-238 | 1972 | Beta Site | LASL, 1973/CDC Rep #887 | NA | 0.081 | 0.025 | fCi m-3 | on-site air monitoring station 23 |
| Air | Pu-238 | 1972 | Pajarito Booster 2 | LASL, 1973/CDC Rep #887 | NA | 0.241 | 0.034 | fCi m-3 | on-site air monitoring station 24 |
| Air | Pu-238 | 1972 | Pajarito Booster 1 | LASL, 1973/CDC Rep #887 | NA | 0.047 | 0.017 | fCi m-3 | on-site air monitoring station 25 |
| Air | Pu-238 | 1972 | TA-36 | LASL, 1973/CDC Rep #887 | NA | 0.051 | 0.012 | fCi m-3 | on-site air monitoring station 26 |
| Air | Pu-238 | 1972 | TA-33 | LASL, 1973/CDC Rep #887 | NA | 0.037 | 0.018 | fCi m-3 | on-site air monitoring station 27 |
| Air | Pu-238 | 1972 | TA-15 | LASL, 1973/CDC Rep #887 | NA | 0.049 | 0.019 | fCi m-3 | on-site air monitoring station 28 |
| Air | Pu-238 | 1972 | TA-49 | LASL, 1973/CDC Rep #887 | NA | 0.052 | 0.020 | fCi m-3 | on-site air monitoring station 29 |
| Air | Pu-238 | 1972 | TA-11 | LASL, 1973/CDC Rep #887 | NA | 0.059 | 0.018 | fCi m-3 | on-site air monitoring station 30 |
| Air | Pu-238 | 1972 | West Jemez Road | LASL, 1973/CDC Rep #887 | NA | 0.094 | 0.021 | fCi m-3 | on-site air monitoring station 31 |
| Air | Pu-238 | 1972 | TA-16 | LASL, 1973/CDC Rep #887 | NA | 0.058 | 0.021 | fCi m-3 | on-site air monitoring station 32 |
| Air | Pu-238 | 1972 | TA-6 | LASL, 1973/CDC Rep #887 | NA | 0.133 | 0.080 | fCi m-3 | on-site air monitoring station 33 |
| Air | Pu-238 | 1972 | TA-3 | LASL, 1973/CDC Rep #887 | NA | 0.404 | 0.080 | fCi m-3 | on-site air monitoring station 34 |
| Air | Pu-238 | 1972 | TA-43 | LASL, 1973/CDC Rep #887 | NA | 0.257 | 0.050 | fCi m-3 | on-site air monitoring station 35 |
| | | | | | | | | | |
| Air | Pu-239 | 1972 | Ta-21 | LASL, 1973/CDC Rep #887 | NA | 0.112 | 0.053 | fCi m-3 | on-site air monitoring station 20 |
| Air | Pu-239 | 1972 | TA-53 | LASL, 1973/CDC Rep #887 | NA | 0.148 | 0.045 | fCi m-3 | on-site air monitoring station 21 |
| Air | Pu-239 | 1972 | Well PM-1 | LASL, 1973/CDC Rep #887 | NA | 0.113 | 0.032 | fCi m-3 | on-site air monitoring station 22 |
| Air | Pu-239 | 1972 | Beta Site | LASL, 1973/CDC Rep #887 | NA | 0.112 | 0.043 | fCi m-3 | on-site air monitoring station 23 |
| Air | Pu-239 | 1972 | Pajarito Booster 2 | LASL, 1973/CDC Rep #887 | NA | 0.106 | 0.038 | fCi m-3 | on-site air monitoring station 24 |
| Air | Pu-239 | 1972 | Pajarito Booster 1 | LASL, 1973/CDC Rep #887 | NA | 0.143 | 0.037 | fCi m-3 | on-site air monitoring station 25 |
| Air | Pu-239 | 1972 | TA-36 | LASL, 1973/CDC Rep #887 | NA | 0.136 | 0.045 | fCi m-3 | on-site air monitoring station 26 |
| Air | Pu-239 | 1972 | TA-33 | LASL, 1973/CDC Rep #887 | NA | 0.099 | 0.037 | fCi m-3 | on-site air monitoring station 27 |
| Air | Pu-239 | 1972 | TA-15 | LASL, 1973/CDC Rep #887 | NA | 0.089 | 0.032 | fCi m-3 | on-site air monitoring station 28 |
| Air | Pu-239 | 1972 | TA-49 | LASL, 1973/CDC Rep #887 | NA | 0.241 | 0.056 | fCi m-3 | on-site air monitoring station 29 |
| Air | Pu-239 | 1972 | TA-11 | LASL, 1973/CDC Rep #887 | NA | 0.099 | 0.030 | fCi m-3 | on-site air monitoring station 30 |
| Air | Pu-239 | 1972 | West Jemez Road | LASL, 1973/CDC Rep #887 | NA | 0.101 | 0.034 | fCi m-3 | on-site air monitoring station 31 |
| Air | Pu-239 | 1972 | TA-16 | LASL, 1973/CDC Rep #887 | NA | 0.076 | 0.036 | fCi m-3 | on-site air monitoring station 32 |
| Air | Pu-239 | 1972 | TA-6 | LASL, 1973/CDC Rep #887 | NA | 0.930 | 0.117 | fCi m-3 | on-site air monitoring station 33 |
| Air | Pu-239 | 1972 | TA-3 | LASL, 1973/CDC Rep #887 | NA | 0.224 | 0.058 | fCi m-3 | on-site air monitoring station 34 |
| Air | Pu-239 | 1972 | TA-43 | LASL, 1973/CDC Rep #887 | NA | 0.122 | 0.050 | fCi m-3 | on-site air monitoring station 35 |

# Table C-5: Selected Groundwater Samples from Mortandad Canyon

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| Groundwater | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 11 | pCi/L | monitoring station 8 |
| Groundwater | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 3 | pCi/L | monitoring station 9 |
| Groundwater | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 1 | pCi/L | monitoring station 10 |
| Groundwater | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 2 | pCi/L | monitoring station 11 |
| Groundwater | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <1 | pCi/L | monitoring station 12 |
| Groundwater | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <1 | pCi/L | monitoring station 13 |
| Groundwater | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 540 | pCi/L | monitoring station 8 |
| Groundwater | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 370 | pCi/L | monitoring station 9 |
| Groundwater | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 170 | pCi/L | monitoring station 10 |
| Groundwater | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 140 | pCi/L | monitoring station 11 |
| Groundwater | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 100 | pCi/L | monitoring station 12 |
| Groundwater | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 55 | pCi/L | monitoring station 13 |
| Groundwater | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 3.2 | pCi/L | monitoring station 8 |
| Groundwater | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.32 | pCi/L | monitoring station 9 |
| Groundwater | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.06 | pCi/L | monitoring station 10 |
| Groundwater | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 11 |
| Groundwater | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.12 | pCi/L | monitoring station 12 |
| Groundwater | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.05 | pCi/L | monitoring station 13 |
| Groundwater | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.44 | pCi/L | monitoring station 8 |
| Groundwater | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.09 | pCi/L | monitoring station 9 |
| Groundwater | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 10 |
| Groundwater | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 11 |
| Groundwater | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 12 |
| Groundwater | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 13 |
| Groundwater | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 65,000 | pCi/L | monitoring station 8 |
| Groundwater | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 49,000 | pCi/L | monitoring station 9 |
| Groundwater | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 64,000 | pCi/L | monitoring station 10 |
| Groundwater | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 52,000 | pCi/L | monitoring station 11 |
| Groundwater | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 84,000 | pCi/L | monitoring station 12 |
| Groundwater | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 120,000 | pCi/L | monitoring station 13 |
| Groundwater | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 400 | pCi/L | monitoring station 8 |
| Groundwater | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 9 |
| Groundwater | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 10 |
| Groundwater | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 11 |
| Groundwater | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 12 |
| Groundwater | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 13 |
| Groundwater | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 6.1 | µg/L | monitoring station 8 |
| Groundwater | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 3.6 | µg/L | monitoring station 9 |
| Groundwater | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 1.3 | µg/L | monitoring station 10 |
| Groundwater | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 1.8 | µg/L | monitoring station 11 |
| Groundwater | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.4 | µg/L | monitoring station 12 |
| Groundwater | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.5 | µg/L | monitoring station 13 |
| Groundwater | Sr-90 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 310 | pCi/L | monitoring station 8 |
| Groundwater | Sr-90 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 180 | pCi/L | monitoring station 9 |
| Groundwater | Sr-90 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 180 | pCi/L | monitoring station 10 |

# Table C-5: Selected Groundwater Samples from Mortandad Canyon

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| Groundwater | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 6.2 | µg/L | monitoring station 8 |
| Groundwater | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 1.8 | µg/L | monitoring station 9 |
| Groundwater | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 3.9 | µg/L | monitoring station 10 |
| Groundwater | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.8 | µg/L | monitoring station 11 |
| Groundwater | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 6.6 | µg/L | monitoring station 12 |
| Groundwater | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.5 | µg/L | monitoring station 13 |
| Groundwater | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 24 | µg/L | monitoring station 8 |
| Groundwater | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 29 | µg/L | monitoring station 9 |
| Groundwater | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <1 | µg/L | monitoring station 10 |
| Groundwater | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <1 | µg/L | monitoring station 11 |
| Groundwater | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 4 | µg/L | monitoring station 12 |
| Groundwater | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <1 | µg/L | monitoring station 13 |
| Groundwater | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.3 | µg/L | monitoring station 8 |
| Groundwater | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 9 |
| Groundwater | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 10 |
| Groundwater | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 11 |
| Groundwater | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.3 | µg/L | monitoring station 12 |
| Groundwater | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 13 |
| Groundwater | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 8 |
| Groundwater | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 9 |
| Groundwater | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 10 |
| Groundwater | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 11 |
| Groundwater | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 12 |
| Groundwater | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 13 |

# Table C-6: Selected Surface Water Samples from Mortandad Canyon

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| Surface Water | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 9 | pCi/L | monitoring station 9 |
| Surface Water | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 8 | pCi/L | monitoring station 10 |
| Surface Water | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 1300 | pCi/L | monitoring station 9 |
| Surface Water | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 800 | pCi/L | monitoring station 10 |
| Surface Water | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 6.8 | pCi/L | monitoring station 9 |
| Surface Water | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 2.1 | pCi/L | monitoring station 10 |
| Surface Water | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 1 | pCi/L | monitoring station 9 |
| Surface Water | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.26 | pCi/L | monitoring station 10 |
| Surface Water | Am-241 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 0.89 | pCi/L | monitoring station 9 |
| Surface Water | Am-241 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 10 |
| Surface Water | U-234 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 6 | pCi/L | monitoring station 9 |
| Surface Water | U-234 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 10 |
| Surface Water | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 38,000 | pCi/L | monitoring station 9 |
| Surface Water | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 50,000 | pCi/L | monitoring station 10 |
| Surface Water | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 1800 | pCi/L | monitoring station 9 |
| Surface Water | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 400 | pCi/L | monitoring station 10 |
| Surface Water | Sr-90 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 160 | pCi/L | monitoring station 9 |
| Surface Water | Sr-90 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 170 | pCi/L | monitoring station 10 |
| Surface Water | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | NA | µg/L | monitoring station 9 |
| Surface Water | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | 7.3 | µg/L | monitoring station 10 |
| Surface Water | chromium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 30 | µg/L | monitoring station 9 |
| Surface Water | chromium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | NA | µg/L | monitoring station 10 |
| Surface Water | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.8 | µg/L | monitoring station 9 |
| Surface Water | cadmium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 1.2 | µg/L | monitoring station 10 |
| Surface Water | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <1 | µg/L | monitoring station 9 |
| Surface Water | lead | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 18 | µg/L | monitoring station 10 |
| Surface Water | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 9 |
| Surface Water | beryllium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 10 |
| Surface Water | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 9 |
| Surface Water | mercury | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 10 |

# Table C-7: Selected Soil and Sediment Samples from Mortandad Canyon

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| soil | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 4 | pCi/g | near TA-50, monitoring station 2 |
| sediment | gross alpha | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 4 | pCi/g | near TA-50, monitoring station 5 |
| soil | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 6 | pCi/g | near TA-50, monitoring station 2 |
| sediment | gross beta | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 20 | pCi/g | near TA-50, monitoring station 5 |
| soil | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.008 | pCi/g | near TA-50, monitoring station 2 |
| sediment | Pu-238 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.044 | pCi/g | near TA-50, monitoring station 5 |
| soil | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.012 | pCi/g | near TA-50, monitoring station 2 |
| sediment | Pu-239 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.38 | pCi/g | near TA-50, monitoring station 5 |
| soil | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 0.021 | µg/kg | soil moisture content/near TA-50, stat. 2 |
| sediment | tritium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | NA | µg/kg | soil moisture content/near TA-50, stat. 5 |
| soil | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | <0.2 | pCi/g | near TA-50, monitoring station 2 |
| sediment | Cs-137 | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 2.1 | pCi/g | near TA-50, monitoring station 5 |
| soil | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 140 | µg/kg | near TA-50, monitoring station 2 |
| sediment | total uranium | 1971 | Mortandad Canyon | LASL, 1972b/CDC Rep # | 1 | 70 | µg/kg | near TA-50, monitoring station 5 |

# Table C-8: Selected Surface Water Samples from Sandia Canyon

| Media | Chemical or Radionuclide | Date(s) | Location | Document/CDC Rep # | Number of Samples | Maximum/ Avail. Value | Units | Comments |
|---|---|---|---|---|---|---|---|---|
| Surface Water | gross alpha | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 2 | pCi/L | monitoring station 9 |
| Surface Water | gross alpha | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <1 | pCi/L | monitoring station 10 |
| Surface Water | gross beta | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 13 | pCi/L | monitoring station 9 |
| Surface Water | gross beta | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 8 | pCi/L | monitoring station 10 |
| Surface Water | Pu-238 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 0.08 | pCi/L | monitoring station 9 |
| Surface Water | Pu-238 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 10 |
| Surface Water | Pu-239 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 0.06 | pCi/L | monitoring station 9 |
| Surface Water | Pu-239 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <0.05 | pCi/L | monitoring station 10 |
| Surface Water | Am-241 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 9 |
| Surface Water | Am-241 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 10 |
| Surface Water | U-234 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 9 |
| Surface Water | U-234 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 10 |
| Surface Water | tritium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 3,000 | pCi/L | monitoring station 9 |
| Surface Water | tritium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 6,000 | pCi/L | monitoring station 10 |
| Surface Water | Cs-137 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 9 |
| Surface Water | Cs-137 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <400 | pCi/L | monitoring station 10 |
| Surface Water | Sr-90 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 9 |
| Surface Water | Sr-90 | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | NA | pCi/L | monitoring station 10 |
| Surface Water | total uranium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 1.6 | µg/L | monitoring station 9 |
| Surface Water | total uranium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <0.4 | µg/L | monitoring station 10 |
| Surface Water | chromium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 7100 | µg/L | monitoring station 9 |
| Surface Water | chromium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 5600 | µg/L | monitoring station 10 |
| Surface Water | cadmium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 12 | µg/L | monitoring station 9 |
| Surface Water | cadmium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 1 | 2.4 | µg/L | monitoring station 10 |
| Surface Water | lead | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | 13 | µg/L | monitoring station 9 |
| Surface Water | lead | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 1 | <3 | µg/L | monitoring station 10 |
| Surface Water | beryllium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <0.3 | µg/L | monitoring station 9 |
| Surface Water | beryllium | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 1 | <0.3 | µg/L | monitoring station 10 |
| Surface Water | mercury | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 2 | <0.02 | µg/L | monitoring station 9 |
| Surface Water | mercury | 1971 | Sandia Canyon | LASL, 1972b/CDC Rep # | 1 | <0.02 | µg/L | monitoring station 10 |