Chapter 10: The Trinity Test

During the first six months of development work at the Laboratory, the gun method of assembly was the focus of the ordnance program. Up to August 1944, the main focus of activity was the plutonium gun. By August 1944, the high velocity uranium gun had been thoroughly proved in principle but the plutonium gun assembly program was abandoned. The main effort of the Laboratory was now directed to the mounting difficulties of the implosion program. The proposal for implosion assembly was to use a plastic flow tamper and active material under high-explosive impact. The first advantage of the implosion weapon over the gun weapon was its much shorter time of assembly. This was of special importance for the assembly of plutonium due to its expected high neutron background, which would make predetonation a serious danger (Hawkins 1961). The implosion-assembled, plutonium-based design[i] was by far the more complicated than the gun-assembled design. A test of that device was considered necessary because of the "enormous step" from theory and experiments to production of a combat weapon and the realization that, if the device failed over enemy territory, "the surprise factor would be lost and the enemy would be presented with a large amount of active material in recoverable form."[ii]

Document Review

Internal Los Alamos technical reports (many with LA- and LAMS- prefixes) in the LANL Reports Collection and the document holdings of the LANL Records Center and Archives were the primary sources of information about the development of the implosion weapon and the Trinity test program. These collections were reviewed and copies of relevant documents were requested for public release. Information from interviews with Trinity participants, Web sites, the Nuclear Testing Archives in Las Vegas, news archives, and books available from the popular press were also incorporated into this summary of information regarding the Trinity test.

Preparations for the Test

Test Organization

A test of the implosion bomb was considered essential by the director and most of the group and division leaders of the Laboratory. The first preparations for a test were made in March 1944, when Group X-2 was formed in the Explosives Division headed by George Kistiakowsky. The duties of the X-2 group under Kenneth Bainbridge included making preparations for a field test in which blast, earth shock,

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[i] Implosion-assembled weapons were designed on the principle of compressing the fissile material to super-criticality by detonation of a high-explosive implosion system.
[ii] "The July 16, 1945 Trinity Bomb Test," September 1945. LANL Archives Collection A-1984-019.

neutron, and gamma radiations would be studied and complete photographic records would be made of the explosion and any atmospheric phenomena associated with it. This work was initially set up under Section X-2C, with L. Fussell Jr. in charge.

In May 1945, a temporary organization was formed consisting of seven groups designated TR-1 through TR-7 (TR for Trinity). Organizationally, the test was called Project TR, and for reasons of secrecy the test site was referred to as T Site prior to the test. Personnel from R, G, O, F, and X Divisions and military men from the SED (Special Engineering Detachment) were reassigned to this "division" until the test was completed (Bainbridge 1976). Project Trinity was led by K. T. Bainbridge, with Frank Oppenheimer (brother of J. Robert Oppenheimer) serving as his Aide. Responsibilities of the TR groups were as follows:

- TR-1, headed by John H. Williams:
  construction, procurement, transportation, timing, communications
- TR-2, headed by J. H. Manley:
  measurements of air blast and earth shock
- TR-3, headed by R. R. Wilson:
  physics measurements: prompt alpha, delayed neutron and gamma radiation
- TR-4, headed by J. M. Hubbard:
  meteorology
- TR-5, headed by J. E. Mack:
  spectrographic and photographic measurements
- TR-6, headed by B. Waldman:
  air blast airborne measurements
- TR-7, headed by L. H. Hempelmann:
  medical, including instruments, the monitoring group, and first aid
- Special Assignments:
  four searchlight crews, an announcer, and weather advisers

J. Robert Oppenheimer and George Kistiakowsky stated in a 1944 memo that "if we do not have accurate test data from Trinity, the planning of the use of the gadget over the enemy territory will have to be done substantially blindly" (Jones 1985).

Site Selection and Construction

Bainbridge's group considered eight sites[i] for testing the first implosion weapon— three in New Mexico, two in California, one in Texas, and one in Colorado. The Los Alamos scientists established the following criteria for the site:

[i] Besides the Jornada del Muerto, the other sites in New Mexico were the Tularosa Basin near Alamogordo, the lava beds (now the El Malpais National Monument) south of Grants, and an area southwest of Cuba and north of Thoreau. Possible sites outside New Mexico were: an Army training area north of Blythe, California, in the Mojave Desert; San Nicolas Island (one of the

- flat terrain to minimize effects of the blast and to facilitate easy construction of roads and communication lines;
- sufficient distance from populated areas but close to Los Alamos to minimize travel between the two sites;
- clear and sunny weather on average to permit the extensive collection of optical data;
- and convenience to good rail transportation.

The Manhattan Project's military head, Major General Leslie R. Groves, added conditions that the area be about 17 by 24 mi in size and that it have no Indians on it, the latter being so that he would not have to deal with Secretary of the Interior Harold Ickes, whom he thought would cause difficulties (Groves 1962). The final site selection was made in late August 1944 by Groves. When Groves discovered that in order to use a California location he favored he would need the permission of its commander, General George Patton, Groves quickly decided on the second choice, the *Jornada del Muerto*[i]. This was because General Groves did not want anything to do with the flamboyant Patton, who Groves had once described as "the most disagreeable man I had ever met" (Szasz 1984).

Bainbridge, a Harvard physicist assigned by J. Robert Oppenheimer to oversee preparations for the bomb test and base camp, chose the 18- by 24-mi tract of land in the northwest corner of the *Jornada del Muerto* (Journey of Death) valley east of the Rio Grande in the New Mexico desert (Bainbridge 1976, Jones 1985). As soon as the Air Force's commanding general for the New Mexico district approved Bainbridge's request to have a section of the Alamogordo Bombing and Gunnery Range turned over to the Manhattan Project, Bainbridge called Oppenheimer to tell him the good news and urged that they pick a code name for the site as soon as possible. Oppenheimer was familiar with a book of John Donne's poems, and the opening line of the one he recalled was "Batter my heart, three-person'd God; for, you as yet but knock, breathe, shine, and seek to mend..." One theory is that Oppenheimer said "we'll call it Trinity" based on that poem (Lamont 1965).

Another theory is that Oppenheimer selected the name with reference to the divine Hindu trinity of Brahma (the Creator), Vishnu (the Preserver), and Shiva (the Destroyer). Oppenheimer had an avid interest in Sanskrit literature (which he had taught himself to read), and following the Trinity test is reported to have recited a passage from the Bhagavad-Gita (Radiochemistry Society 2007).

A great deal of time was initially wasted in land surveys due to inadequate maps. Maps were requested through the Security Office in June 1944 but many were never received. The maps that were eventually

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Channel Islands) off the coast of Southern California; on Padre Island south of Corpus Christi, Texas, in the Gulf of Mexico; and in the San Luis Valley of south central Colorado, near today's Great Sand Dunes National Monument (USDOE 1994).

[i] This area was a short cut on the Camino Real, the King's Highway that linked Mexico to Santa Fe, used to avoid a valley that was too narrow for supply wagons. Sixty miles of desert, with very little water and numerous hostile Apaches, led the Spanish conquerors of New Mexico to assign the name.

used were obtained by ordering all the geodetic survey maps and most of the grazing service and county maps for the state of New Mexico; aerial mosaics and land status maps had to be “scrounged”. Aerial photographs of the northwest corner of the Alamogordo Air Base were obtained from the Air Force and assembled into a photo mosaic that was used with a transparent overlay to determine locations for the main instrument shelters that would not be in washes. The selected land tract permitted separation from nearest habitation by a minimum of 12 mi to the north and west. Moreover, the government controlled the land out to 18 miles on the east. The nearest towns in any direction were 27-30 miles away and the prevalent winds were from the west (Bainbridge 1976). A memorandum providing justification for the construction and equipment requirements for the proposed scientific measurements was given to Oppenheimer in October 1944. A construction company contracted by the Army [J. D. Leftwich Company of El Paso, TX] completed the first facilities at the camp by the end of December 1944, and a small Military Police detachment under Lt. Bush arrived from Los Alamos to provide security for the site (Bainbridge 1976). Shortly after, a much larger group of scientists, technicians, medics, civil service personnel, and construction workers arrived.

There was a maze of roads to be built, hundreds of miles of wire to be strung over and under the ground, a complete communication system to be installed, buildings to be erected, supplies, equipment, and personnel to be transported between Los Alamos and Trinity, all under the cloak of extreme secrecy (LASL 1979). By early 1945, there were more than 200 residents at the Trinity Base Camp. Civilian construction crews aided by construction personnel from Los Alamos built additional facilities in the spring of 1945 to ready the site for the bomb test, which was scheduled for early summer (Jones 1985).

As depicted in Fig. 10-1 through Fig. 10-3, facilities at the test site included:

- A Shot Tower (located at “Ground Zero,” the central reference point)
- Base Camp (located 10 miles to the south-southwest)
- South Shelter (located 10,000 yd (about 6 mi) to the south; housed VIPs and the control center for the test)
- North Shelter (located 10,000 yd to the north; housed personnel, instruments, and searchlight crews)
- West Shelter (located 10,000 yd to the west; housed personnel, cameras, and searchlight crews)

The three shelters, which were heavily-built wooden bunkers reinforced with concrete and covered with earth, were code named Able, Baker, and Pittsburgh (National Atomic Museum 2007). Test personnel made use of the McDonald Ranch House for final assembly of the bomb’s plutonium core. Trinity Base Camp included stables, a blacksmith shop, water storage tanks, a hay barn, officers’ quarters, a supply room, mess hall, barracks, latrine, P.X. and day room, coal storage, infirmary, laboratory, technical warehouse, office, garage, gasoline storage tanks, fire station, engineering office, plumbing shop, electrical shop, carpentry shop, and drinking water tanks (Merlan 2001).

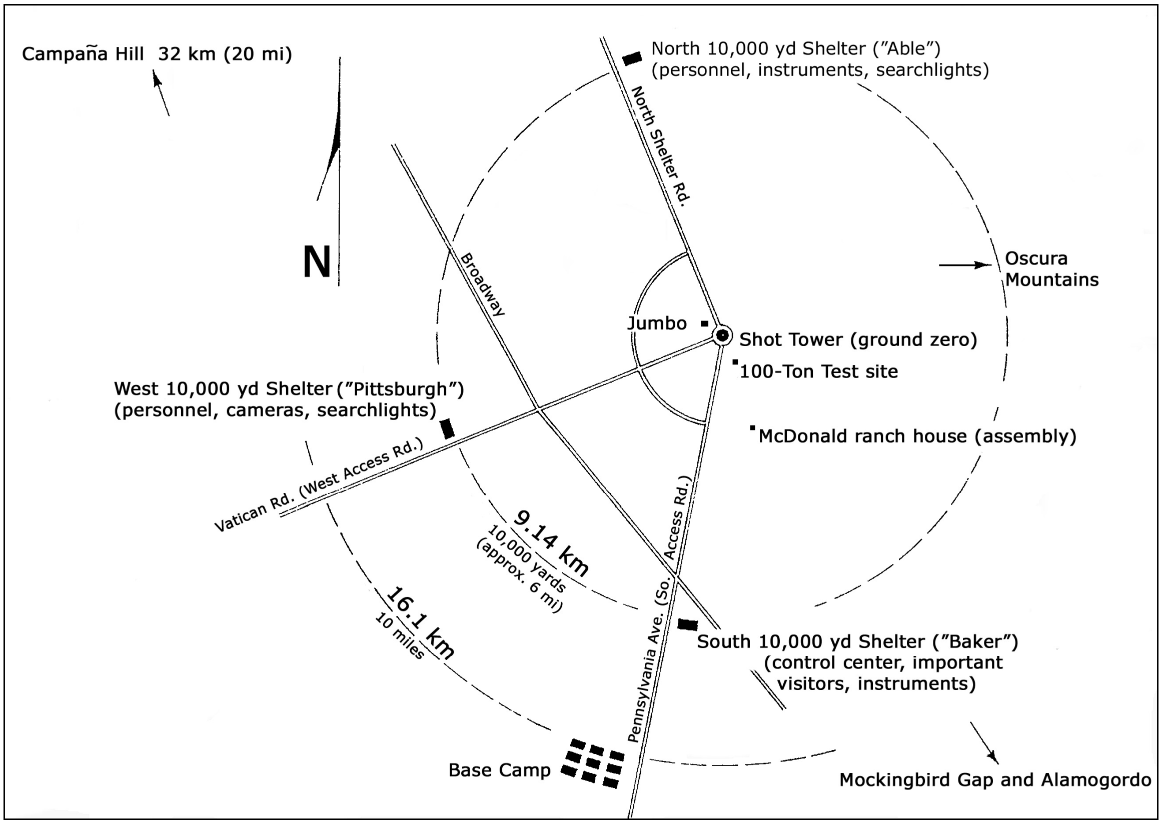

Fig. 10-1. Map of facilities at the Trinity Test Site (based on Lamont 1965)

The 100-Ton Test

In the summer of 1944, a "100-ton test shot" using conventional high explosives (HE) was proposed to calibrate the blast and earth shock measuring equipment at the Trinity site and to serve as a dress rehearsal for the summer 1945 test. The "first" Trinity test occurred on May 7, 1945 at the New Mexico site 800 yd south of what would be ground zero for the July 16 test. It was the first chance to test experimental data under explosion conditions. Since explosions of more than a few tons of TNT have different characteristics than lesser amounts, 108 tons of HE (Composition B, a mixture of TNT and the explosive RDX) brought in from Fort Wingate[i] and a small volume of radioactive solution (to simulate the radioactive products of the nuclear test) were detonated atop a 20-foot platform (Fig. 10-4) so that dispersion could be characterized and instruments could be calibrated (LASL 1979, Jones 1985, Radiochemistry Society 2007).

[i] Erickson (1946) described the explosive charge for the 100-Ton Test as 3590 wooden boxes (179,500 lbs) of flaked TNT and 744 boxes (32,044 lbs) of pelletized Composition B.

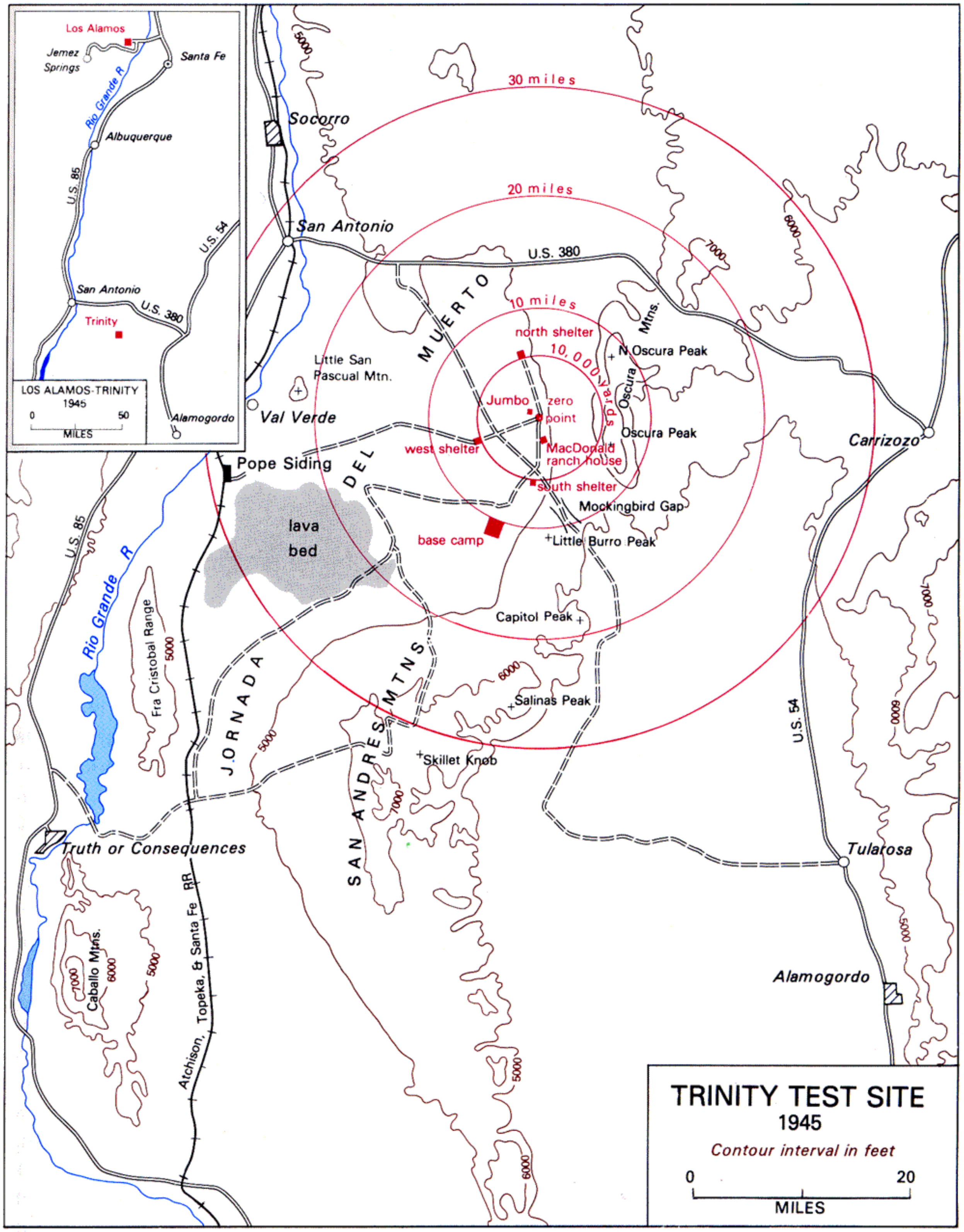

Fig. 10-2. Location of the Trinity Test Site and Nearby Towns (from Jones 1985)


Figure 10-3: Trinity Test Reference Map
CDC's
LAHDRA
Los Alamos Historical Document Retrieval & Assessment
ChemRisk
ENSR INTERNATIONAL
National Forest
Wildlife refuge
US military reservation
County boundary
Township and Range
Land grant
Hard surface, heavy-duty road
Hard surface, medium-duty road
Improved light-duty road
Unimproved, dirt road
Railroad
Telephone line
Aqueduct
Vegetated area
Lava
Building, occupied
Building, unoccupied
Mine
Cattle tank
Water tank
Well
Spring
Water body
Peak
Benchmark
5 mi
10,000 ft
5 km
Map produced by cARTography by Andrea Kron 4/26/07
30 miles
20 miles
10 miles
TRINITY
SITE
GROUND ZERO
Chamber No. 2
Chamber No. 1
North Shelter
South Shelter
West Shelter
Guard Post 1
Guard Post 2
Guard Post 4
Guard Post 5
Guard Post 6
Guard Post 7
McDonald Ranch Hdqtrs
McDonald Ranch (abandoned)
WHITE SANDS PROVING GROUND
ALAMOGORDO BOMBING RANGE
JORNADA DEL MUERTO
OSCURA MOUNTAINS
CHUPADERA MESA
THE MALPAIS
"HOT CANYON"
Searchlight Station L-8
CIBOLA NATIONAL FOREST
BOSQUE DEL APACHE NATIONAL WILDLIFE REFUGE
Rio Grande
Socorro
Carthage P.O.
Carthage
Campana Hill
San Antonio
Bingham
Bingham P.O.
Adobe
White Store
North Oscuro
South Oscuro Pk
Oscuro Pk
Bursum
Hansenburg Ranch
Hansonburg Mining District
Broken Back Crater
LAVA
Carrizozo
Claunch
Valverde
Pope Siding
Lemitar
Escondida
Florida
Fite Ranch
Bruton Ranch
"Red and Gray Hills"
Nolda Ranch
Ratliff Ranch
Dean Ranch
Sedillo Coker Hdqtrs
Lucero Ranch
SOCORRO CO.
LINCOLN CO.
SIERRA BLANCA
LINCOLN NATIONAL FOREST
34°00'
33°45'
33°30'
107°00'
106°45'
106°30'
106°15'
106°00'
380
54
85
60

Box after wooden box of HE were stacked until approximately 100 tons were in the pile. An irradiated uranium fuel slug from a Hanford reactor was dissolved using the apparatus shown in Fig. 10-5 and poured into flexible tubing threaded through the high explosive (Sugarman 1945). The solution introduced into the pile had beta activity of 1,000 Ci and gamma activity of 400 Ci.

Fig. 10-4. Boxes of High Explosives Stacked for the "100-Ton Test"

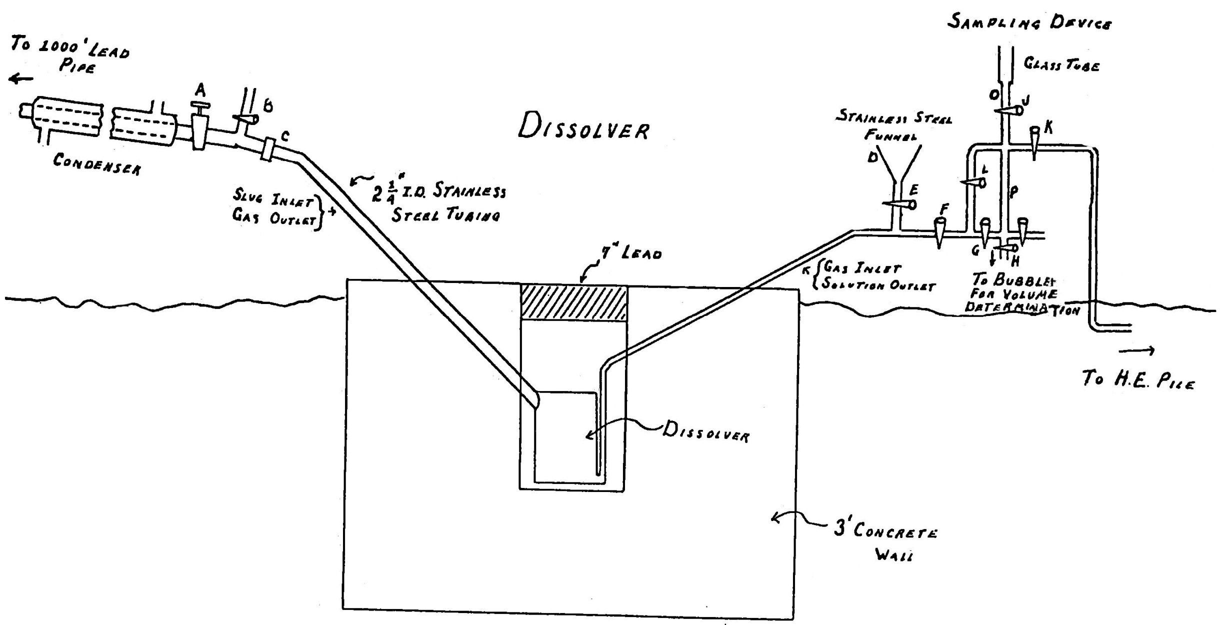

Fig. 10-5. Diagram of the equipment used to dissolve an irradiated uranium fuel slug from a Hanford reactor for dispersion in the 100-Ton Test at Trinity Site (Sugarman 1945). The fuel slug entered the dissolver via the pipe from the left, by which off-gases were also exhausted. The radioactive solution exited via the tubing to the right, into the stack of boxed high explosives.

The blast (Fig. 10-6) compressed and blew the surrounding earth into a saucer-shaped crater, expelling about 40% of the dirt. A scaling up the RaLa shots suggested that 10% of the activity would remain in the soil within a 300-ft radius. However, only 2% of the activity of the dissolved radioactive material was deposited in the crater out to a distance of 450 ft from the center. This indicated that simple scaling didn't account for the increase in updraft with increased explosive charge.

According to Richard C. Tolman, a physicist who has an advisor to General Leslie Groves, the explosion of the "100-ton test" aroused little comment in neighboring towns, but the illumination and sound were detected at the Alamogordo Air Base 60 mi away by a pre-warned observer. According to Hempelmann, the level of activity in the crater was low enough to be safe for several hours of exposure. The dissolving unit was covered with dirt and surrounded by a guard fence. Suggestions for improvement in facilities and procedure included paved roads to protect personnel and instruments from dust, more vehicles, more vehicle repairmen, and more telephone lines (Bainbridge 1976, Hoddeson et al. 1993).

Fig. 10-6. Views of the "100-Ton Test" Blast at 1, 2, and 3 seconds after detonation.
(photos obtained at nuclearweaponarchive.org/Usa/Tests/Trinity.html)

Date Selection and Meteorology

July 4 was the original target date for the second test at Trinity, the nuclear test. In mid- June, Oppenheimer said that July 13 was the earliest possible date for the test, however, the laboratory's "Cowpuncher Committee" had primary responsibility for coordination and scheduling for Trinity. The committee was composed of S. K. Allison, former Director of the Metallurgical Laboratory, Kistiakowsky, Captain Parsons, C. C. Lauritsen, Bacher, and Hartley Rowe, a former Technical Advisor to General Eisenhower. It was organized "to ride herd" on the implosion program.

After a review of developments on June 30, the Committee advanced the test date to July 16 to permit inclusion of certain additional vital experiments. The committee held its first meeting in early March 1945. This group met often and published a semimonthly report called "The Los Alamos Implosion

Program" that presented in detail the current status of the work. Since Secretary of War Henry Stimson would be attending the Potsdam Conference starting on July 16, a test date of July 14 was requested by Groves so the results of the test would be known. The bomb test team, however, insisted on a test date of July 17. On July 7, Oppenheimer told Groves the test could take place on the 16th, but no earlier, since all parts of the Gadget (code name for the Fat Man implosion bomb) would not be ready before July 16 (Jones 1985).

The date of the Trinity test depended on the availability of components and on the weather. Haze, dust, and mirage effects would interfere with photographic measurements. Overcast skies would make flying more difficult for the airplanes to drop instruments. Winds had to be favorable to keep the radioactive cloud away from inhabited areas to the east and north. Each group was asked to specify the best weather conditions for their experiment, and meteorologist Jack Hubbard tried to find a date to match their requirements. Hubbard initially projected that the best dates for the Trinity test would be between July 18 and 21, with July 12 through 14 as second best. The preferred time was several hours before dawn (Hoddeson et al. 1993).

Meeting the weather needs of all groups proved impossible, and the groups had to compromise. Optimum winds would draw the radioactive cloud away from the nearby towns and break it up rapidly. Winds from the northwest through southwest were judged best and were typically the driest, therefore keeping thunderstorms from washing additional radioactivity down to the earth's surface. No one was sure how high the radioactive cloud would go. An inversion layer over nearby towns, which were 27-30 miles away, would prevent material from touching down in those areas. Although thunderstorms were expected for July 16, Hubbard agreed that the shot could be made, even if conditions would not be optimal for all the planned experiments (Hoddeson et al. 1993).

Scheduling Impacts on Planning of Protective Actions

After the date for the Trinity test was set at 16 July 1945, Dr. Louis Hempelmann recalled that "there was feverish activity on our part to make the town monitoring program flexible enough to adapt itself to whatever wind conditions prevailed when the test was ready" (Hacker 1987). In anticipation that the people living in towns and on ranches in the immediate vicinity might have to be evacuated to avoid radioactive fallout, army intelligence agents led by Maj. T. O. Palmer searched the countryside trying to locate, list, and map every person living within a 40-mi radius of ground zero in case evacuation became necessary (Hoffman 1947, Bainbridge 1976, Hacker 1987). The Army stationed a detachment of 160 enlisted men with vehicles at Socorro and other strategic points along main highways a few miles north of the site. The Army also detailed 25 Counterintelligence Corps (CIC) members to towns and cities up to

100 mi from the site with instructions to summon evacuation troops if they were needed, and to help manage public reaction to the blast (Jones 1985).

Instrumentation, Experiments, and Cameras Put into Place

At a conference in Oppenheimer's office on December 23, 1944, diagnostic experiments for the Trinity test were categorized as essential, desirable, or unnecessary. Essential experiments include the pressure of the blast wave and the time spread in the firing of the detonators. Desirable experiments included photographic and spectrographic analyses of the fireball, and measurement of the earth's motion during the explosion in case any lawsuits were brought against the laboratory for blast damage. All other experiments were deemed unnecessary (Hoddeson et al. 1993).

Much emphasis was placed on measuring the energy in the blast wave. This was achieved by using a pair of beryllium-copper diaphragm microphones to record the peak pressure following the explosion because it was suggested that the change in pressure generated by the blast wave was the only quantity that could be measured accurately from 20 miles away during combat use. A more sophisticated method was also used, which consisted of making a precise measurement of the velocity of sound at the site of explosion and comparing it to the velocity of the blast wave. Spring-loaded piston gauges, water-filled pistons, diaphragm box gauges, and ball and cylinder gauges were calibrated to record a range of peak pressures from the blast. The mechanical gauges were insensitive to electrical disturbances and acted as backup to the electrical methods (Hoddeson et al. 1993).

Plans were made to estimate the energy of the bomb in several ways, including determination of the number of fissions by measuring the number and intensity of the gamma rays emitted. Prompt and delayed gamma rays could be measured separately. Ionization chambers were used to measure the prompt gamma rays. The ionization from the delayed gamma rays was measured by "suitable devices" placed within 10 or 20 miles of the gadget. The number and energy of the gamma rays could be used to derive the number of fissions and calculate the efficiency and yield of the bomb (Hoddeson et al. 1993).

The energies and distribution of neutrons from the blast provided another method for calculating yield, but they were difficult to measure since they were more likely to be degraded or absorbed. Plans were made to measure time-integrated neutron flux using gold foils in protective tubes placed between 300 and 1000 meters from ground zero that would be activated by slow neutrons from the blast. Arrangements were also made to perform direct examinations of the soil from the area near the blast for plutonium and fission products to support estimation of the efficiency of the explosion. Two lead-lined tanks (Fig. 10-7) with trap doors on their undersides were equipped to recover soil samples from the Trinity site crater (Hoddeson et al. 1993).

Another essential measurement was the time interval between the detonation of high explosives and the beginning of the chain reaction to determine if the nuclear reaction was started by the initiator or began prematurely. The degree of simultaneity of the detonators required for an efficient implosion was unknown at the time. The presence of an informer switch at each detonator superseded the requirement for the test to be an exact duplicate of the gadget as it would be used in combat (Hoddeson et al. 1993).

A variety of instruments were put into place to measure earth motion, including the change in position of stakes, geophones, and seismographs. Seismograph measurements were made on site at the North Shelter (10,000 yards from ground zero) and at Base Camp and off site at Tularosa, Carrizozo, and San Antonio (Hoddeson et al. 1993).

Fig. 10-7. One of two lead-lined tanks prepared to recover soil samples from near ground zero

The primary purpose of the photography effort was to have a good photographic record for spectrographic and yield analysis. Different stages of the explosion required different film speeds, lenses and exposures, and no one knew the amount or kind of light that would be emitted during the explosion. Fastax cameras taking 10,000 frames per second were put into place to record minute details of the beginning of the explosion. Fastax cameras placed 800 yd from the blast were protected by a steel and glass bunker and were mounted on a sled that could be pulled out of the contaminated area by a chain attached to one of the lead-lined tanks. They would exhaust their film supplies in several hundredths of a second. Rotating-drum spectrograph cameras were positioned to monitor light wavelengths emitted by the fire ball, and pinhole cameras were put into place to recorded gamma rays. The only available well-exposed color photograph of the explosion was taken by Jack Aeby, a 21-year old Los Alamos scientist and amateur photographer (Hoddeson et al. 1993) using his own camera, which Italian physicist Emilio Segre had secured permission for him to carry on site to record the activities of Segre’s group as they studied delayed gamma rays (Savage and Storm 1965).

The “Jumbo” Containment Vessel

The construction of a large pressure vessel to contain the rare and valuable plutonium if the first atomic bomb was a dud was considered in the winter and spring of 1944. Other recovery methods considered included a below-ground sand cone (sand to high explosive weight ratio 15,000:1) and a cylindrical tank of water (water to high explosive weight ratio 50:1 or 100:1). Although a container could possibly allow scientists to recover the plutonium, all proposed blast, earth shock, and optical measurements would be rendered useless by the presence of the vessel, so this idea was not popular with the scientists. The final design for Jumbo was a 25 ft by 12 ft cylinder with hemispherical ends that weighed 214 tons. It was built by Babcock and Wilcox Corporation in Barberton, Ohio and shipped in early April 1945 on a specially fabricated railcar to a railroad siding at Pope, New Mexico (Fig. 10-8). A 64-wheeled trailer pulled by two tractors was used to move the vessel the 25 miles from Pope to the test site (Jones 1985). By March 1945, all recovery methods were abandoned because sufficient plutonium for a second test would be available from Hanford, and Jumbo was never used. However, it was erected 800 yards from ground zero in case it was needed for a second test (Hoddeson et al. 1993).

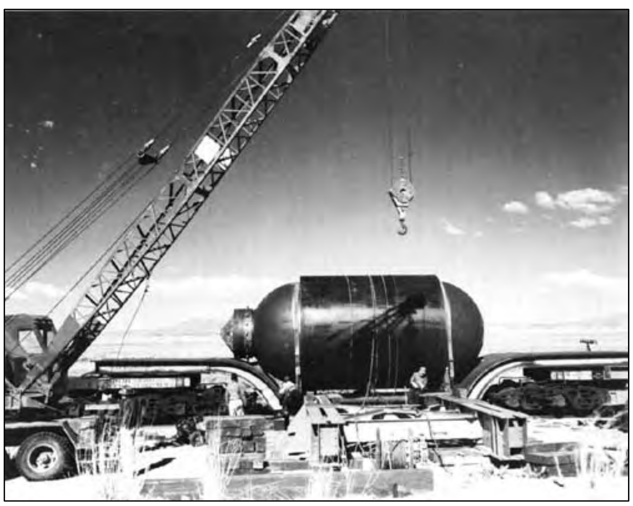


Fig. 10-8. The "Jumbo" containment vessel being loaded on a specially made, 64-wheel trailer at the Pope, NM railroad siding (left) and making its 25-mi trip to the Trinity site on a road constructed for that purpose (right).
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Final Preparations

Two complete sets of high explosive castings were available on July 10. Prior to July 7, there had not been enough lens castings to make a complete charge. Kistiakowsky and Bradbury picked the best looking pieces for the Trinity assembly and designated the rest for the full-scale magnetic Creutz test of the gadget to be conducted at Pajarito Canyon without active material. The Trinity charge was assembled on July 12 at V Site in Los Alamos and started on its journey to the Trinity site at midnight, arriving just before noon on the 13th (Bainbridge 1976). Kistiakowsky wrote that he chose to leave just after midnight on Friday the 13th because he "believed in unorthodox luck" (Kistiakowsky 1980).

On July 12, two scientists arrived from Los Alamos in an army sedan with the ^{239}Pu core for the implosion device. An interview with Phillip Morrison revealed that he rode down to Trinity with the weapon core. He and Marshall Holloway, both G Division engineers, were designated as the Pit Assembly team in April 1945 and were responsible for placing the core into the gadget during final assembly. Morrison didn't remember a great deal about the ride to the Trinity site, but did recall that he was "rather afraid of the fast driving young woman who drove us down there with the convoy, who was really a high-speed… pedal to the floor all the way. That driver was the scariest thing" (Morrison 1999). General Farrell signed a receipt for the active material, formally completing the transfer from the scientists to the Army (Jones 1985). All components were in place except the detonating system at 5:45 pm on July 13. The device was hoisted to a metal shed on a platform atop a 100-ft steel shot tower, a surplus Forest Service fire-watch tower (Fig. 10-9 and Fig. 10-10) (National Atomic Museum 2007).

Fig. 10-9. The steel shot tower used for the Trinity test

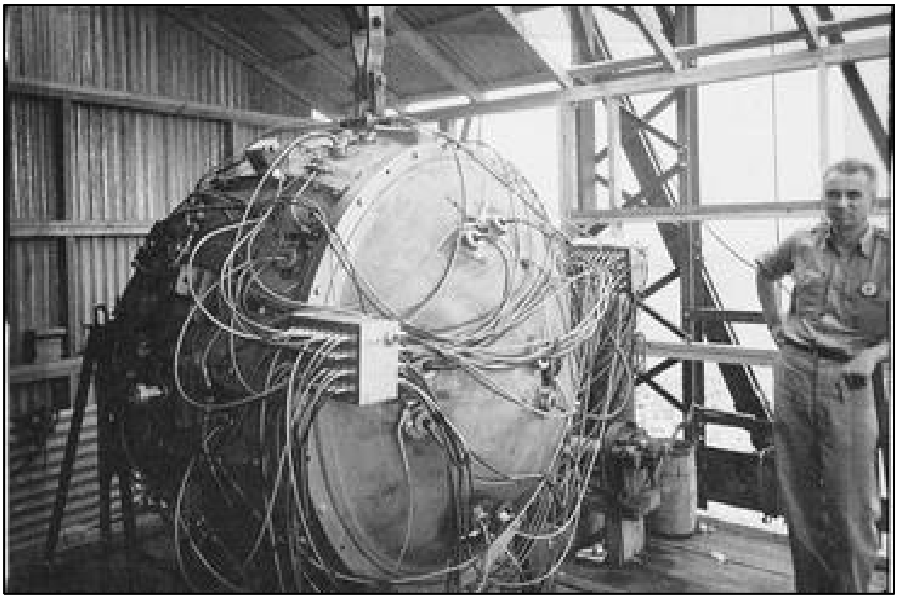

Fig. 10-10. The assembled "Gadget" sits in the metal shed atop the 100-ft metal test tower. To the right in this photo is Norris Bradbury, who would follow Oppenheimer as LASL Director

A truckload of mattresses were piled up under the Gadget in case it fell (Hoddeson et al. 1993). The detonator group completed the firing circuit and technicians added an apparatus for experiments. By 5:00 pm on July 14, the device was ready for the test.

Observers including Office of Scientific Research and Development (OSRD) Director Vannevar Bush and National Defense Research Committee Chairman James Conant arrived with General Groves on Sunday, July 15. The large contingent from Los Alamos arrived in three buses around 3:00 am on the morning of July 16, just before the scheduled test time of 4:00 am. The weather was rainy and there were occasional flashes of lightning. General Groves and Oppenheimer decided to delay the shot for an hour and a half. The rain stopped at 4:00 am. Shortly before 5:00 am, with the wind still blowing in the “right” direction, they gave the go-ahead signal for the test (Jones 1985).

Health and monitoring organization preparations addressed issues of cloud and trail contamination. According to Hempelmann, the activity of the cloud would vary with the efficiency of the explosion and it would need to be monitored until it was dispersed since it was a potential hazard to the local population. If loose dust from the crater and the surrounding area rose to 10,000 feet and fell at a normal rate there might be danger to towns 30 miles away, due to a prediction of 7 R h^{-1} from fission products and the ^{239}Pu tolerance dose being exceeded in 22 h. Hubbard assured all concerned that the meteorological conditions that could affect the cloud were predictable, including low humidity, temperature inversion, winds above the inversion, atmospheric lapse rate, and heating of the earth. Low humidity would exclude a thunderstorm created by the blast and heat effects that could cause precipitation of the active material over a small area. The inversion layer would retard particles from falling until the morning thermals mixed the active material more thoroughly. A 30 mph wind to the SE above the inversion layer would carry the cloud beyond the nearby towns. A stable lapse rate would allow the fire ball to ascend until it reached a higher inversion at 20,000 ft and preclude heavy active particles from falling on a small area. The usual heating of the earth would break the inversion layer and move air in an ascending manner. Hubbard predicted that contaminated material thrown into the air could be suspended for weeks (Bainbridge 1976).

A betting pool was started by Los Alamos scientists on what the yield of the Trinity device would be (National Atomic Museum 2007). Yields from zero to 45,000 tons of TNT (45 kilotons) were selected. Bainbridge was furious when he heard discussions of the possibility that the blast would be hot enough to ignite the nitrogen in the atmosphere and would annihilate the human race (Hacker 1987). This possible outcome had been suggested by Edward Teller, but fears were quashed by intensive studies by Hans Bethe and others that were documented by Teller and Emil Konopinski in December 1943. These studies concluded that the safety factor was “at least a factor of 60” (Rosen 2002).

Bus loads of visitors from Los Alamos and elsewhere started arriving near the Trinity Site around 2:00 a.m. on July 16. Many of them who had no duties for the test set up on Campaña Hill[i] (about 32 km to the northwest of ground zero) to watch the event. This included Ernest O. Lawrence, Hans Bethe, Edward Teller, Robert Serber, Edward McMillan, James Chadwick, and Richard Feynman (Merlan 2001).

At the time of the detonation, 99 project personnel (about 76 civilian and 23 military) were in the three shelters: 29 at North, 37 at West, and 33 at South. Harvard president James Conant, General Groves, and Vannevar Bush observed the test from a slit trench at Base Camp; J.R. Oppenheimer, Kenneth Bainbridge, George Kistiakowsky, Thomas Farrell, Donald Hornig, and Samuel Allison watched from the South 10,000 Shelter, which served as the control point (Maag and Rohrer 1982, Merlan 2001). Groves and Oppenheimer purposefully watched the test from different locations, separated by some distance, so that if one were killed, the other could likely continue to manage the project.

The Trinity Test

The Trinity “Gadget” was detonated on Monday, 16 July 1945 at 5:29 a.m. Mountain War Time at latitude 33°28’- 33°50’, longitude 106°22’- 106°41’, UTM coordinates 630266 on the Alamogordo Bombing Range, New Mexico. The time is not known with certainty, because scientists experienced difficulty in picking up station WWV for a time check (Bainbridge 1976, Maag and Rohrer 1982).

[i] “Campaña” also appears as “Campania,” “Campagne,” or “Campagna” in various sources. These spellings might have been adopted to help those with little knowledge of the Spanish language pronounce the word.

Observations/Descriptions

The nuclear blast (Fig. 10-11) created a flash of light brighter than a dozen suns (National Atomic Museum 2007). The light was seen over the entire state of New Mexico and in parts of Arizona, Texas, and Mexico. The resultant mushroom cloud rose to over 38,000 ft within minutes, and the heat of the explosion was 10,000 times hotter than the surface of the sun. At 10 mi away, this heat was described as like standing directly in front of a roaring fireplace. Data from hundreds of instruments recorded what occurred that morning. The blast was more powerful than expected, however, and many instruments and experimental devices were ruined (Lamont 1965). A brilliant yellow light was seen as far away as Albuquerque and Los Alamos to the north, Silver City New Mexico to the west, and El Paso Texas to the south. A sensation of heat persisted as a huge ball of fire took shape and transformed into a moving orange and red column. Out of this spectrum rose a narrower column that rapidly spilled over to form a giant white mushroom cloud surrounded by a blue glow. As the glow began to fade, observers at the base camp felt the pressure of the shock wave and its rumble reverberated for more than five minutes in the surrounding hills (Jones 1985). General Thomas Farrell, Deputy to Gen. Leslie Groves, said that "The effects could well be called unprecedented, magnificent, beautiful, stupendous and terrifying. No man-made phenomenon of such tremendous power had ever occurred before."   "I am become Death, the Destroyer of Worlds" was reportedly said by J. Robert Oppenheimer. Dr. Kenneth Bainbridge, Director of Trinity Test, said "Now we are all sons-of-bitches."

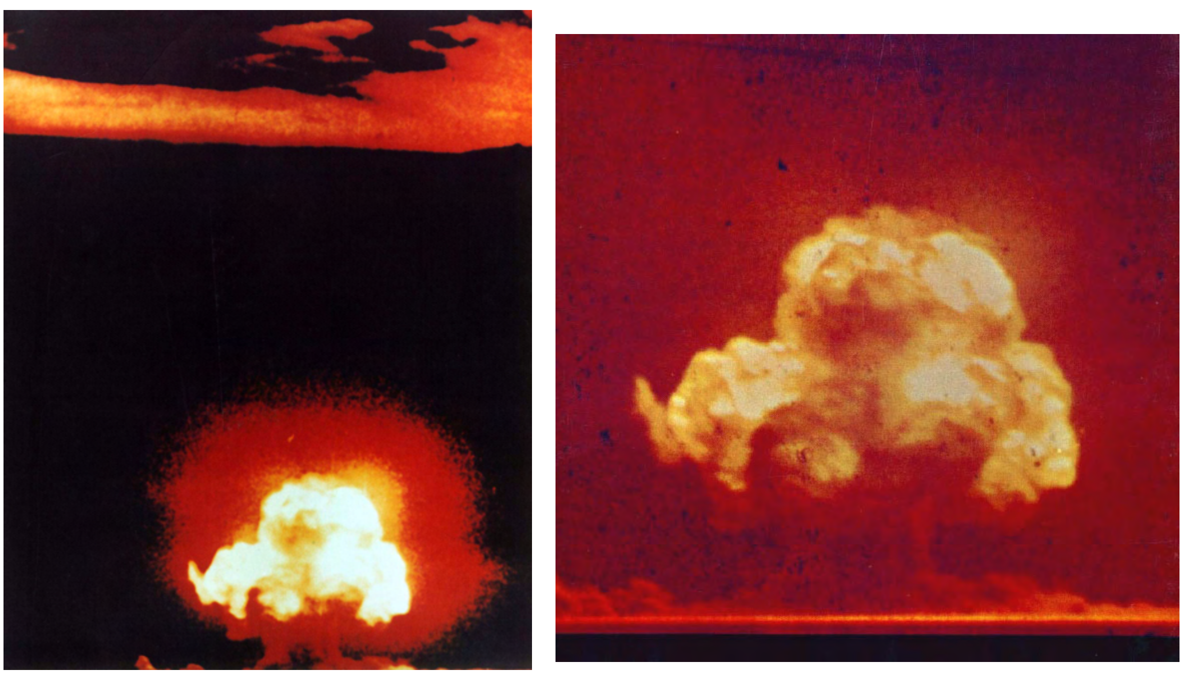

Fig. 10-11. Two images from the only well-exposed color photograph available for the Trinity blast, taken by Los Alamos scientist and amateur photographer Jack Aeby from near Base Camp. As Aeby later said, "It was there so I shot it."

The crew sent to Searchlight Station L-8 to illuminate and observe the cloud from the blast recorded that, at t + 15 minutes, the cloud was divided into three parts—a dense white mushroom cloud, a flat, fairly long red dust cloud, and a reddish-brown column that seemed to come from ground zero (Blair et al. 1945b). The three-man crew was located 19.5 miles from ground zero, to the northeast, as shown in Fig. 10-12. At t + 30 minutes, the high mushroom cloud had moved directly toward their position, and had "taken on the shape of the North American part of the western hemisphere" while the "lower red-brown cloud and column took on the shape of a question mark, while the brown dust seemed to be still emanating from position 0." Radioactive material started to descend upon Searchlight Station L-8 between t + 90 minutes and t + 120 minutes (Blair et al. 1945b). The radiation level peaked at its highest level at 8:25 a.m., and remained constant through 9:15 a.m., after which it started to decline (Blair et al. 1945b).

Physicist Otto Frisch had been taken to a spot about 32 km from ground zero (probably on Compaña Hill). Because he couldn't find his assigned dark glasses as the countdown progressed in the dark that early morning, Frisch initially turned away from ground zero but later recorded the following observations (Frisch 1979):

> "And then, without a sound, the sun was shining; or so it looked. The sand hills on the edge of the desert were shimmering in a very bright light, almost colourless and shapeless. The light did not seem to change for a couple of seconds and then began to dim. I turned round, but that object on the horizon which looked like a small sun was still too bright to look at. I kept blinking and trying to take looks, and after another ten seconds or so it had grown and dimmed into something more like a huge oil fire, with a structure that made it look a bit like a strawberry. It was slowly rising into the sky from the ground, with which it remained connected by the lengthening grey stem of swirling dust; incongruously, I thought of a red-hot elephant standing balanced on its trunk. Then, as the cloud of hot gas cooled and became less red, one could see a blue glow surrounding it, a glow of ionized air; a huge replica of what Harry Daghlian … [saw just over five weeks later at Omega Site in Los Alamos] when his assembly went critical and signaled his death sentence. The object, now clearly what has become so well known as the mushroom cloud, ceased to rise but a second mushroom started to grow from its top; the inner layers of the gas were kept hot by their radioactivity and. Being hotter than the rest, broke through the top and rose to even greater height. It was an awesome spectacle; anybody who has ever seen an atomic explosion will never forget it. And all in complete silence; the bang came minutes later, quite loud though I had plugged my ears, and followed by a long rumble like heavy traffic far away. I can still hear it."

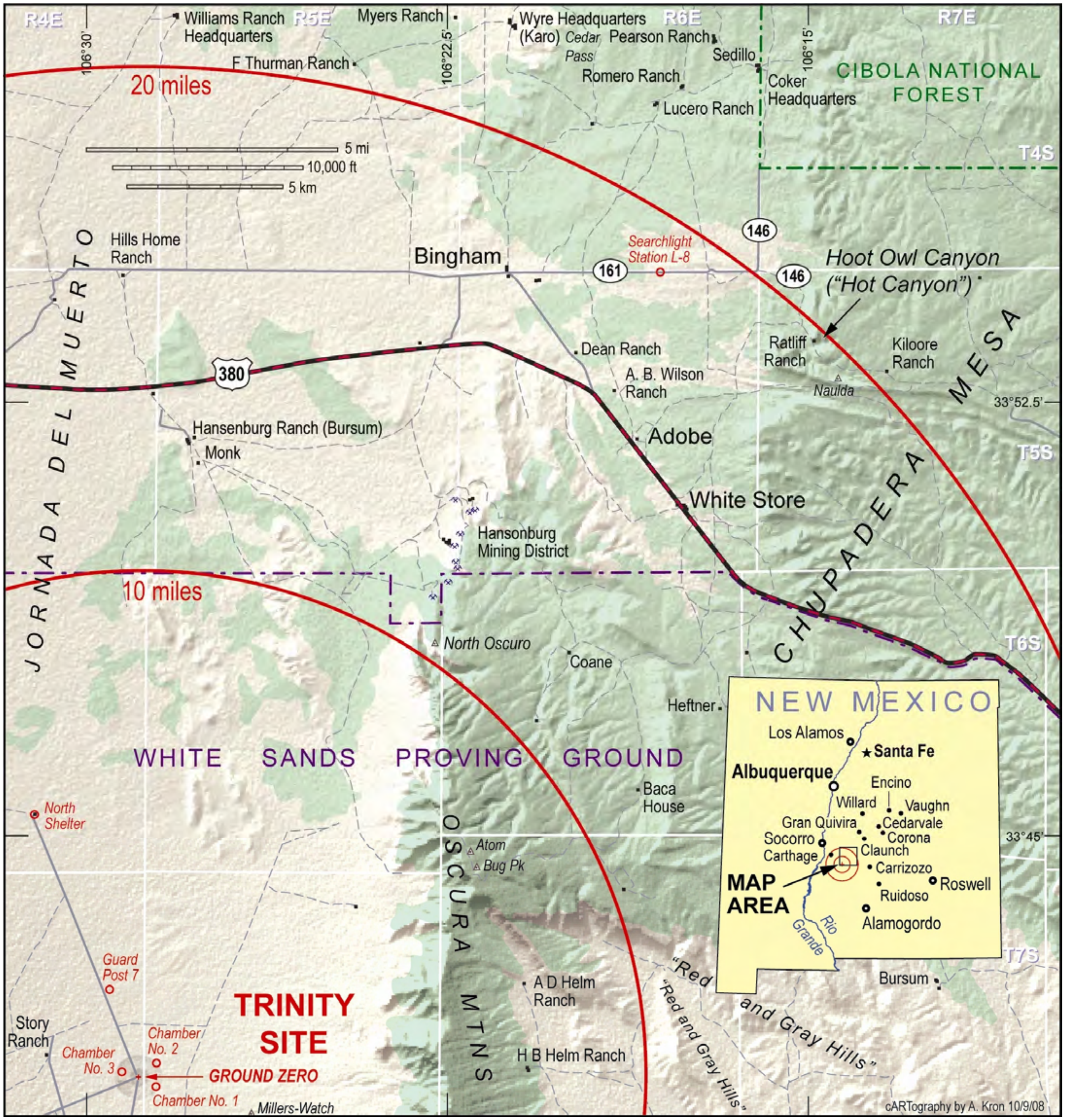

Fig. 10-12. Map of areas to the northeast of the Trinity Site where highest off-site radiation levels were measured after the July 1945 shot.

Less than a half hour after the test shot, General Groves called his secretary in Washington, D.C. to pass on word of the test to Secretary Stimson. He reported that the strength of the explosion was at least “satisfactory plus and perhaps far greater than estimated” (Lamont 1965).

Trajectory of the Cloud and Observations of Fallout

Up to the time of the shot and for the first half hour after the shot, information about the direction of travel of the cloud was vague. A 20 mi h^{-1} wind was blowing from the southeast toward Guard Gate 2[i] to the northeast of ground zero. It was thought that the radioactive cloud would move in a line toward the northwest from ground zero, but the cloud did not travel in that direction (Hoffman 1947).
Col. Stafford Warren, Chief of the Manhattan Project’s Medical Section, documented the following in a July 21, 1945 report to Gen. Groves (Warren 1945):

> “The energy developed in the test was several times greater than that expected by scientific group. The cloud column mass and top reached a phenomenal height, variously estimated as 50,000 to 70,000 feet. It remained towering over the northeast corner of the site for several hours. This was sufficient time for the majority of the largest particles to fall out. Various levels were seen to move in different directions. In general the lower one-third drifted eastward, the middle portion to the West and northwest, while the upper third moved northeast. Many small sheets of dust moved independently at all levels and large sheets remained practically in situ. By zero plus 2 hours, the main masses were no longer identifiable except for the very high white mass presumably in the stratosphere.
>
> By 0800 hours the monitors reported an area of high intensity in a canyon 20 miles northeast of zero. … Intensities in the deserted canyon were high enough to cause serious physiological effects.
>
> The distribution over the countryside was spotty and subject to local winds and contour. It skipped the nearby highway #380 (20 mi. N.E.) except for low intensities which were equaled at twice and three times the distance. It is presumed that the largest outfall occurred in the N.E. quadrant of the site. This can only be explored by horseback at a later date.”

Between 6:00 and 7:00 am, the wind direction changed from southeasterly to southwesterly[ii], and the cloud was traveling northeast at 15 mi h^{-1}, at altitude 35,000 ft, and rising about 14,000 ft h^{-1}. Monitors found readable gamma radiation 1.7 h after the shot 19 mi from ground zero. This indicated that the active

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[i] Guard Gates or Guard Posts were typically just tents or parked trucks along the roadside used to provide shelter for security guards that controlled access to the various areas of the Trinity Site.

[ii] Although not adhered to in many historical reports, this summary follows the convention of describing wind directions as the directions that the wind is blowing *from*.

dust falling from high altitudes had been caught by the northwesterly wind near the ground and blown in the direction of Socorro (Hoffman 1947).

The cloud drifted northeastward at about 10 mi h^{-1}, dropping its trail of fission products across a region measuring 100 mi long and 30 mi wide (Lamont 1965). In the deep ravines northeast of the Trinity site, where cattle grazed, the radioactivity settled in a white mist (Lamont 1965). The off-site monitors feared inversions and solar heating of air in the canyons, which could cause thermal updrafts that can lead to sudden wind shifts and carry airborne contamination beyond the expected limits, possibly dumping it in some remote area unknown to the monitors (Lamont 1965).

William Wrye, whose house was 20 mi northeast of Trinity, tells that "for four or five days after that, a white substance like flour settled on everything" (Albuquerque Journal News 1995). And rancher M. C. Ratliff said that "the ground immediately after the shot appeared covered with light snow," adding that for several days afterward, especially at dawn and dusk, "the ground and fence posts had the appearance . . . of being frosted" (Hacker 1987).

As the cloud drifted beyond Carrizozo, with monitoring teams in full chase, scientists realized that the monitors had overreached the limits of their radio contact with base camp. As fallout was dropping on northern communities like Coyote, Ancho, and Tecolote, the monitors were unable to relay the results to Stafford Warren at Base Camp (Lamont 1965). Even as officials at base camp were advising Washington that the fallout danger was diminishing, the monitors were racing back toward Trinity with reports that fallout had reached a number of areas beyond their jurisdiction, such as Vaughn (Lamont 1965).

The [visible] cloud from the Trinity blast appears to have dissipated over the vicinity of Vaughn, 96 mi from ground zero. It appears that the main cloud wrapped itself around Gallinas Peak, 65 mi north of the site, and broke up (Lamont 1965). There is evidence that fallout from the Trinity test traveled as far as Indiana. In the fall of 1945, the Kodak Company observed some spotting on their film and they traced it back to contamination in their cardboard. Dr. J.H. Webb, a Kodak employee, studied the matter and concluded that the ^{141}Ce contamination must have come from a nuclear explosion somewhere in the U.S. In fact, it came from the Trinity Test (Webb 1949).[i] Fallout from the explosion had contaminated the river water that the paper mill in Indiana had used to manufacture the cardboard pulp. Recognizing the sensitivity of this information, Dr. Webb kept his discovery secret until 1949 (Webb 1949). Airplanes equipped with filters followed the Trinity cloud across Kansas, Iowa, Indiana, upstate New York, New England, and out to sea (Blair et al. 1945a).

[i] Memorandum by Julius H. Webb, "Fogging of film by radioactive contaminants at Eastman Kodak Company," 15 March 1949. In: LANL Archives Collection A-1999-019, Box 69, Folder 14.

Witnesses from Outside the Project

Due to the intense secrecy surrounding the test, accurate information of what happened was not released to the public until after the second atomic bomb had been dropped on Japan three weeks later. Without being officially informed, many people in New Mexico were well aware that something extraordinary had happened the morning of July 16, 1945. The blinding flash of light, followed by the shock wave, had made a distinct impression on people who lived within a radius of 160 miles of ground zero. Windows were shattered 120 miles away in Silver City, and residents of Albuquerque saw the bright light of the explosion on the southern horizon and felt the tremor of the shock waves moments later (National Atomic Museum 2007).

In spite of the "no fly" order, pilot John Ellison, a flight engineer, and four trainees took off from Roswell Air Field in a B-29 just before 5 am on July 16, 1945. They were on a training mission for the 9- to 12-h bombing missions planned over Japan, and had been cleared to fly to California. About 42 min into the flight, they were 18,000 ft over the northern part of the Sacramento Mountains bordering the White Sands Missile Range when they saw a searing light and the red fireball of the first atomic bomb test. Ellison estimated that he and his crew were 15-20 mi from ground zero and may have been the closest persons to witness the test from the air. This is likely to be true, as the two B-29 observation planes were unable to take off from Kirtland Field due to bad weather, including heavy clouds and thunder storms (Groves 1945). Ellison radioed the tower in Roswell and they told him to get the plane back. Later he learned that authorities associated with the atomic test overheard his radio transmission and ordered the base to call in the planes (Santa Fe New Mexican 2005).

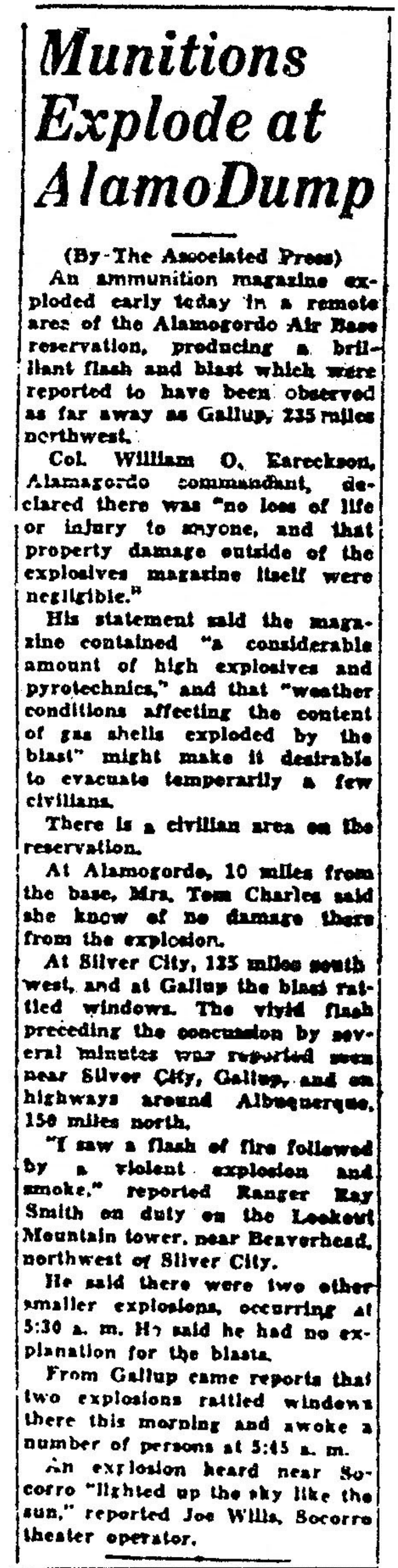
The "Cover Story"

An officer from General Grove's headquarters gave the cover story to the commander of the Alamogordo Air Base to be issued as soon as the test had occurred. Another officer was stationed in the Associated Press office in Albuquerque to suppress any stories that might alarm the public. Groves also arranged with the Office of Censorship in Washington, D.C. to keep news of the explosion from getting into newspapers in other parts of the country. The Army issued an order grounding all commercial planes and suspending all flights from nearby military installations (Jones 1985). Groves modified the cover story to fit the exact circumstances of the test and gave permission to the Associated Press at Albuquerque to release it as follows:

> "Alamogordo, N.M., July 16. The commanding officer of the Alamogordo Air Base made the following statement today: Several inquiries have been received concerning a heavy explosion which occurred on the Alamogordo Air Base reservation this morning. A remotely located ammunition magazine containing a considerable amount of high explosives and pyrotechnics exploded. There

was no loss of life or injury to anyone, and the property damage outside of the explosive magazine itself was negligible. Weather conditions affecting the content of the gas shells exploded by the blast may make it desirable for the Army to temporarily evacuate a few civilians from their homes" (Jones 1985).

Fig. 10-13 shows an article that resulted from release of the cover story.



Munitions Explode at AlamoDump

(By The Associated Press)

An ammunition magazine exploded early today in a remote area of the Alamogordo Air Base reservation, producing a brilliant flash and blast which were reported to have been observed as far away as Gallup, 235 miles northwest.

Col. William O. Eareckson, Alamagordo commandant, declared there was "no loss of life or injury to anyone, and that property damage outside of the explosives magazine itself were negligible."

His statement said the magazine contained "a considerable amount of high explosives and pyrotechnics," and that "weather conditions affecting the content of gas shells exploded by the blast" might make it desirable to evacuate temporarily a few civilians.

There is a civilian area on the reservation.

At Alamogordo, 10 miles from the base, Mrs. Tom Charles said she know of no damage there from the explosion.

At Silver City, 135 miles south west, and at Gallup the blast rattled windows. The vivid flash preceding the concussion by several minutes was reported seen near Silver City, Gallup, and on highways around Albuquerque, 150 miles north.

"I saw a flash of fire followed by a violent explosion and smoke," reported Ranger Ray Smith on duty on the Lookout Mountain tower, near Beaverhead, northwest of Silver City.

He said there were two other smaller explosions, occurring at 5:30 a. m. He said he had no explanation for the blasts.

From Gallup came reports that two explosions rattled windows there this morning and awoke a number of persons at 5:45 a. m.

An explosion heard near Socorro "lighted up the sky like the sun," reported Joe Wills, Socorro theater operator.

Fig. 10-13. An Associated Press article that resulted from the Trinity cover story

Experimental Results

Immediately after the test, Sherman M-4 tanks, painted white, equipped with their own air supplies, and lined with two inches of lead went out to explore the crater area. The lead added 12 tons to each tank's weight, but was considered necessary to protect the tanks' occupants from the radiation levels at ground zero. The tank's passengers found that the 100-foot steel tower had virtually disappeared, with only the metal stumps of its legs imbedded in concrete remaining (USDOE 1994).

The most important result was that the implosion device worked. The yield was three times larger than predicted. T-Division's predictions were between 5 and 10 kilotons. Radiochemical analysis of the soil samples gave an estimated yield of 18,600 tons of TNT, quite close to the currently accepted value of 20 to 22 kilotons. Some of the observers tried to estimate the yield while watching the test. Enrico Fermi performed a fairly simple experiment, in which he tore a sheet of paper into pieces and dropped them as the blast wave passed his location. They moved about 2.5 ft, which Fermi calculated to be equivalent to 10,000 tons of TNT.

The Socorro Chieftain carried the following item after the Trinity Test, but before the true story of what had happened was released:

"An explosives magazine at the Alamogordo air base blew up Monday morning [*see 'The Cover Story,' below*], and the flash, sound and shock were seen, heard and felt in Socorro, more than 100 miles away . . . The flash was intensely white and seemed to fill the entire world. It was followed by a large crimson glow. The flash lasted only a second or so. It was so bright that Miss Georgia Green of Socorro, blind student at the University of New Mexico, being driven to Albuquerque by her brother-in-law, Lieutenant Joe Wills, asked, "What's that?"

The blast measuring devices performed well, but the gamma ray measuring devices were overloaded. The higher gamma radiation fogged the motion picture films slightly and ruined the measurements of detonator simultaneity. Few neutron detectors survived the blast. Seven of the gold foils were recovered. No gauges with 200 ft of ground zero survived. The seismographs detected a tremor at the North Shelter and at San Antonio 28 mi away. The yield and size of the fire ball prompted scientists to specify the height of the Hiroshima and Nagasaki bombs at 1,850 ft (Hoddeson et al. 1993). According to Bainbridge, 1% of the fission products were left in the crater and its vicinity (Bainbridge 1976). Due to the presence of dust around ground zero "a large region of the countryside was contaminated by fission products." This is discussed in more detail in a LASL report (Hirschfelder et al. 1945).

Because of the storm conditions on the morning of the 16th, Oppenheimer asked Waldman and Alvarez not to fly over ground zero to drop the gauges that would radio data back to the B-29s because the flight would be too dangerous (Hoddeson et al. 1993).

Local Conditions

Fig. 10-14 shows an aerial photograph of the area around ground zero at 28 h after the test. The blackened area shows the radius of intense heat that burned off all the vegetation. The blast effect in this area and resulting updraft of hot gases removed a thin layer of soil and burned debris from the blast area.

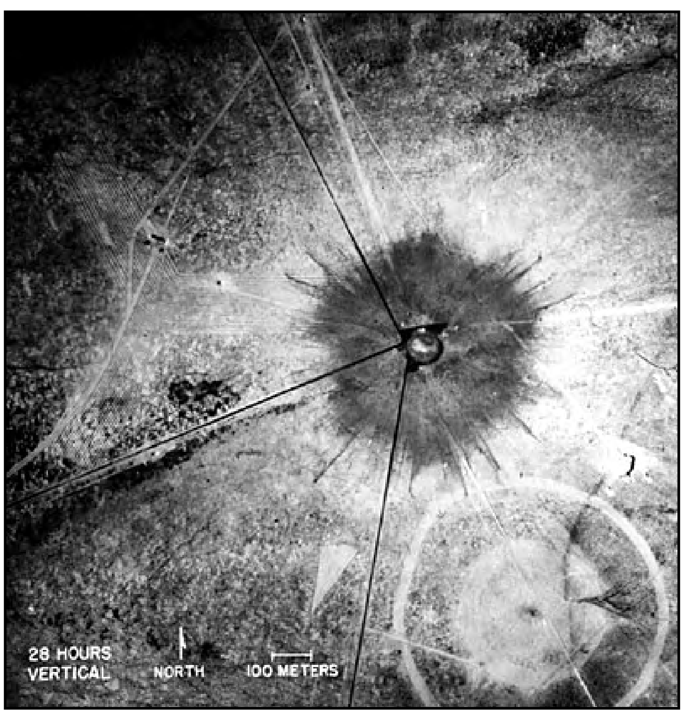


Fig. 10-14. Aerial view of the Trinity ground zero (center) at 28 h after the shot. The circle to the lower right is from the 100-Ton test, with its detonation point exactly 1 mi distant.

Measurement and Management of Off-site Consequences

While not much was said publicly about measurements of off-site fallout from the Trinity test for years after the shot, advance planning and preparation did take place before the test to establish the ability to measure off-site radioactivity and promote public safety to the extent allowed during war time, when many other objectives were competing.

Competing Priorities for Secrecy, Security, Safety, and Avoidance of Litigation

Writing 25 y after the Trinity test, General Groves described what had been six immediate military requirements for adequate Project Trinity security (Hacker 1987). While Groves' recollections might have reflected 1970 as well as 1945 views, the list of requirements for security is informative:

- Barring strangers from the test site;
- Preventing harm to project members;
- Reducing chances that outsiders could learn of the explosion;
- Safeguarding the public from fallout;
- Planning for emergency evacuation; and
- Forestalling any national press reports that might alert Japan.

Testing an atomic bomb on American soil, no matter how remote the site, clearly threatened the secret of the atomic bomb project— the most violent man-made explosion in history could hardly pass unseen. It was important that the Japanese not be alerted, and elaborate public safety precautions seemed likely only make the event more noticeable (Hacker 1987). But fortunately, it was thought, to some degree the same measures that kept Trinity safe from prying eyes could also help keep the public safe from the test and testers safe from lawsuits (Hacker 1987).

When general Groves visited Los Alamos in April 1945 for a briefing on Trinity plans, his first questions were about legal matters (Hacker 1987). He was concerned about damage or harm from earth shock, air blast, and toxic effects, and felt that valid records would help secure the army against damage claims. This is why, for example, 20 government agents were stationed in towns up to 100 miles from ground zero on shot day, equipped with recording barographs, seismographs, and recording radiation meters to measure remote shock, blast, and radiation (Hoffman 1947, Bainbridge 1976, Hacker 1987).

Until just weeks before the test, fallout simply appeared to be a minor problem. Los Alamos "plans to send out radio equipped cars provided with instruments for measuring alpha particle and gamma ray intensities in outlying areas" met Groves' approval (Hacker 1987). "On the basis of these measurements, evacuation of inhabitants could be carried out if necessary." Groves dismissed any thoughts of advance warning to nearby ranchers and townsfolk, because “the danger seemed modest given the proper weather” (Hacker 1987). Keeping the secret forced some compromises with safety (Stannard 1988).

Shortly before the field test, updated calculations provided indication that fallout could be more substantial and widespread than originally thought (Hacker 1987, Stannard 1988). While there was considerable discussion regarding whether assumptions on which those calculations were based were overly pessimistic, the fallout calculations completed shortly before June 23, 1945, provided predictions that were sobering, and establishment of monitoring and evacuation plans seemed more prudent (Hacker 1987).

Figure 10-15 shows the locations of ranches, farms, towns, camps, and towns within approximately 40 miles of Trinity ground zero that are labeled on USGS 1:250,000 maps issued in 1954.

General Groves and the Manhattan Project’s Medical Director, Stafford Warren, are said to have known that the Army was not eager to pursue too diligently the possibilities of widespread fallout (Lamont 1965). The specter of endless lawsuits haunted the military, and most of the authorities simply wanted to put the whole test and its aftereffects out of sight and mind (Lamont 1965).

Potential Pathways of Public Exposure

Members of the public could have been exposed to radiation and radioactive materials from the Trinity event by a number of pathways, including:

1. Direct, prompt radiation from the blast itself
2. Direct, external irradiation from the cloud passing overhead or near by
3. Direct, external irradiation from being immersed in the cloud
4. Direct, external irradiation from contamination deposited on the ground
5. Direct, external irradiation from contamination deposited on the skin, hair, or clothing
6. Internal dose from inhalation of airborne contamination
7. Internal dose from inhalation of resuspended fallout particles
8. Internal dose from ingestion of contaminated food products

Initial radiation from fission and other processes in the explosion ceased in less than a minute, as delayed neutrons lasted only seconds; radiation from the fireball, although substantial, decreased as the square of distance and was further attenuated by air. Ten thousand feet from ground zero, well within site boundaries, radiation was too low to detect (Hacker 1987).

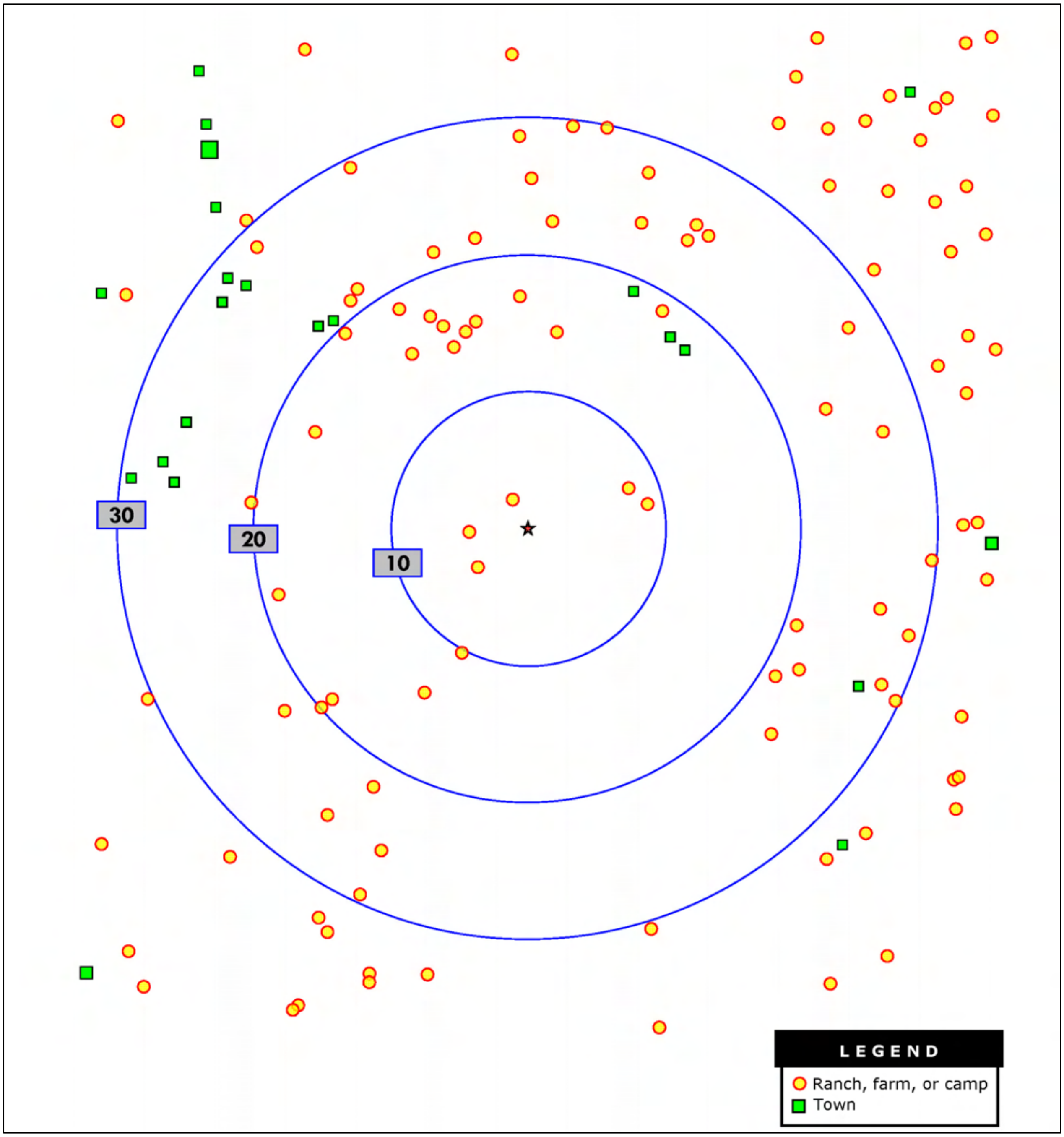


Fig. 10-15. Locations of ranches, farms, camps, and towns within about 40 mi of Trinity Site ground zero based on USGS 1:250,000 maps issued in 1954. Circles are at radii of 10, 20, and 30 mi.

Pathway 1 was apparently relatively insignificant to members of the public. Had it been significant, it would have shown up on the "remote sentinel robot ionization chambers" that spotted the main access roads at distances between 400 and 10,000 yd (Hoffman 1947, Hacker 1987) and the recording gamma meters that were stationed in local towns.

The post-shot radiological monitoring program conducted by Los Alamos scientists with the assistance of military personnel addressed, to the extent possible with the equipment available at the time, pathways 2, 3, and 4 dealing with direct exposure from radioactivity in the cloud or deposited on the ground. This was accomplished by the collection of data by field monitoring crews, which were analyzed and reported in documents assembled by Hoffman and others.

The post-shot radiological monitoring program, however, did not focus on assessment of pathways 5 through 8. No monitoring for contamination on the bodies of members of the public was performed (such as frisking or collection of wipe or wash samples). This pathway was found to be important for livestock, because they stay mostly outdoors, do not wear clothes, and do not bathe. It was reported that cattle that grazed on Chupadera mesa suffered local beta burns and temporary loss of dorsal hair (Hempelmann 1947, Hacker 1987, Stannard 1988). Patches of hair grew back discolored. The Army bought 75 head in all from ranchers; the 17 most significantly marked were kept at Los Alamos, while the rest were shipped to Oak Ridge for long term observation. It was estimated that the doses required to produce such effects were between 4,000 and 50,000 R, most likely around 20,000 R (Hacker 1987).

While there is documentation that samples of airborne particles were taken using ten Filter Queen air samplers (modified vacuum cleaners), and soil samples were reportedly taken using large-mouthed jars provided to monitoring crew members (Hoffman 1947), we have located no analyses of subsequent radiometric or radiochemical analyses of these samples, nor have we located risk assessments that address exposures to Trinity workers or to members of the public from internally deposited radioactivity following inhalation or ingestion of radioactivity from the Trinity blast.

Dose Limits and Action Levels for Public Evacuation

The recovery of data from the Trinity test took precedence over general safety standards (Hacker 1987). The 0.1 R d^{-1} standard for workers in day to day operations at Los Alamos was replaced for Trinity by a statement that “no person should (of his own will) receive more than five (5) r at one exposure” (Hacker 1987). When pressed to decide how high of a radiation exposure to call safe for those with no part in, or knowledge of, the Trinity test (that is, members of the public), Hempelmann and Nolan assured Bainbridge that a total dose of 68 R spread over two weeks “would certainly not result in permanent injury to a person with no previous exposure . . . It would probably not even cause radiation sickness. A normal person could probably stand two to three times this amount without sustaining permanent bodily damage. Fatalities would not result unless ten or more times this dose were delivered” (Hacker 1987, Stannard 1988). Concern focused on immediate hazards, as within the health physics community “the thinking had not yet focused on possible long-term effects” (Stannard 1988).It was clear that evacuation would require an “extreme emergency” (Hacker 1987). Stafford Warren stated that he would begin to worry only if peak exposure rates reached 10 R h^{-1} , and said that the best approach would be to take “measurements for several hours and consider evacuation if total dose reached final total of 60-100 r” (Hacker 1987).

Two days before the test, Warren and Hempelmann agreed to “set the upper limit of integrated gamma ray dose for the entire body over a period of two weeks (336 hours) as 75 roentgens” and also agreed on an “upper safe limit of radiation … [of] 15 r/hr at peak of curve” (Hacker 1987).

Off-Site Monitoring Team Staffing and Positioning

Four two-man, off-site monitoring teams and one five-man team supervised by the chief off-site monitor constituted the off-site monitoring crew led by Joseph Hoffman (
Fig. 10-16). The teams were manned as follows, with initial placement as indicated (Hoffman 1947, Maag and Rohrer 1982):

- Alfred Anderson was with Julian Bernacci at Nogal, NM (about 55 mi ESE)
- Joel Greene was with Charles Nally at Roswell, NM (about 110 mi ESE)
- Carl Hornberger was with Richard Foley at Fort Sumner (about 140 mi NE)
- Robert Leonard was with William McElwreath at Socorro, NM (about 30 mi NW)
- Wright Langham, Phillip Levine, John Magee, Joseph Hirschfelder, and Joseph Hoffman (the chief monitor) were at Guard Gate 2.

The five-man team remained at Guard Gate 2 to assist in evacuation of nearby residents if the cloud from the shot drifted toward the northwest. These residents, specifically the Fite Ranch house and the homes in the town of Tokay, were roughly 15 and 20 mi northwest of ground zero, respectively (Maag and Rohrer 1982). From Guard Gate 2, those monitors could also be dispatched toward Carthage, Bingham, Claunch (about 50 mi NE), and Carrizozo.

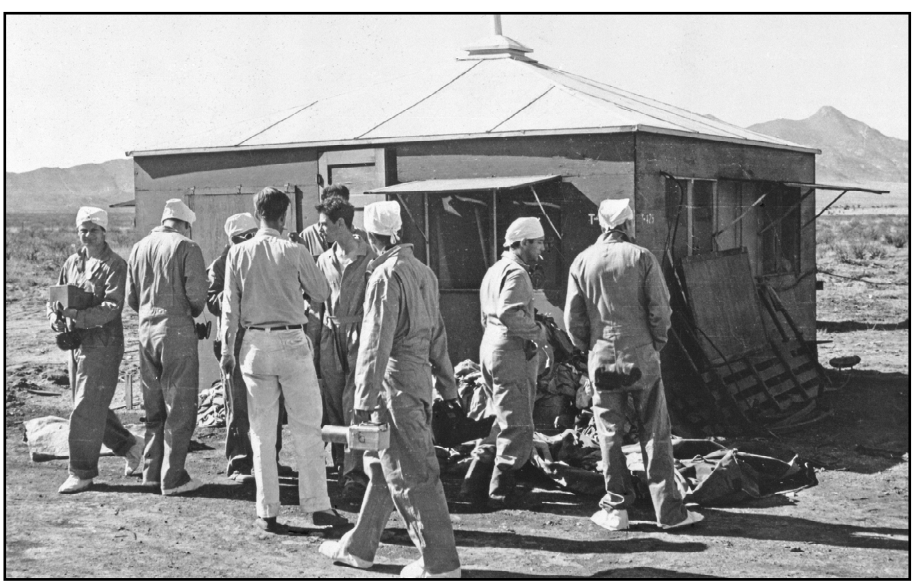


Fig. 10-16. Recovery team and radiation monitoring crew members after the Trinity blast

Equipment Used for Off-Site Monitoring

Each off-site monitoring team was provided with the following equipment (Hoffman 1947):

- A methane filled proportional counter for detecting alpha particle radiation in the presence of beta and gamma radiation.
- A Victoreen Model 247 portable gamma ray survey meter with three ranges.
- A Hallicrafter Model 5 portable Geiger-Mueller survey meter for gamma radiation and mixtures of gamma and beta.
- Large-mouthed bottles for collecting soil samples.
- A map showing names and locations of residents within a radius of 40 mi of ground zero.

Landsverk and Wollan quartz-fiber electrometers ("L & W meters") were also used, at least at Searchlight Station L-8, as were "meters obtained from R. Watts, " also known as Watts-type meters (Blair et al. 1945b, Hacker 1987). All off-site monitoring teams were intended to be in radio or telephone contact with personnel at Base Camp, but communications were problematic and information could not always be shared (Hoffman 1947, Lamont 1965, Maag and Rohrer 1982).

In addition to the instruments carried in automobiles, the following stationary equipment was used (Hoffman 1947):

- The three shelters (North, South, and West) were equipped with an alpha meter, a beta-gamma GM meter, and a survey meter.
- At the Base Camp, a Filter Queen airborne particulate sampler, and a GM recording meter were used.
- At the towns of Tularosa, Hot Springs, San Antonio, and Carrizozo, a Filter Queen, a recording beta-gamma meter, and a seismograph were set up.

Where Off-Site Monitoring Teams Traveled

Based on observed surface winds, it was thought that contamination was blowing in a line toward the northwest from ground zero during the first half hour after the shot. As a result, an early attempt was made to monitor around Fite's Farm just past Guard Gate 2 (see Fig. 10-3). A Military Police officer refused to allow the monitoring team to enter that area, however, until permission was received from Base Camp. That permission came after it was thought that the cloud had passed, so attention was diverted elsewhere. Around 7:11 am, a monitoring team found detectable gamma radiation 19 mi from ground zero in the direction of Socorro (toward the northwest) (Hoffman 1947).

After the path of the cloud appeared to shift toward the northeast, monitors focused on areas along, or near, Route 380 past Carthage and between Bingham and Carrizozo (see Fig. 10-12). Monitoring teams visited Adobe and White Store to the east along Route 380, and some traveled all the way to Carrizozo. Teams traveled north from Bingham on Road 146 to monitor ranches in that area, such as the Coker, Lucero, and Sedillo ranches. Just east of Bingham, the highest levels of elevated radioactivity were found around Searchlight Station L-8 and rugged areas to its southeast. About 2 mi east of the 146/161 junction, Road 146 runs through a steep gorge. The highest exposure rates were found there, which led to it being called "Hot Canyon" (see Fig. 10-12 and Fig. 10-17). Hoffman wrote "since the canyon was hot, extensive measurements could not be made there on account of instrument contamination." (Hoffman 1947)

Puzzled by the high readings reported from Hot Canyon, Drs. Hempelmann and Friedell went to the area on July 17, the day after the shot, and discovered an adobe house hidden from the road, about a mile east of where the highest readings had been taken (Hacker 1987). An elderly couple lived there with a young grandson, several dogs, and assorted livestock (Hoffman 1947, Hacker 1987). The Ratliff ranch had been overlooked by the Army, and it was not on the copies of "Palmer's map of inhabited localities" that monitoring crews were given. A second ranch unknown to the army was discovered later. As it turned out, a couple with the last name of Wilson lived near the Ratliffs, and early reports confused the two residences (Hemplemann 1947, Hoffman 1947, Hacker 1987).

While there is no record of what the exposure rates were at the Ratliff ranch on shot day, since the exposure rates there on the 17th, the doctors decided, were not high enough to warrant "hasty evacuation" (Hacker 1987). As mentioned earlier, rancher M. C. Ratliff said that "the ground immediately after the shot appeared covered with light snow," adding that for several days afterward, especially at dawn and dusk, "the ground and fence posts had the appearance . . . of being frosted" (Hemplemann 1947, Hacker 1987).

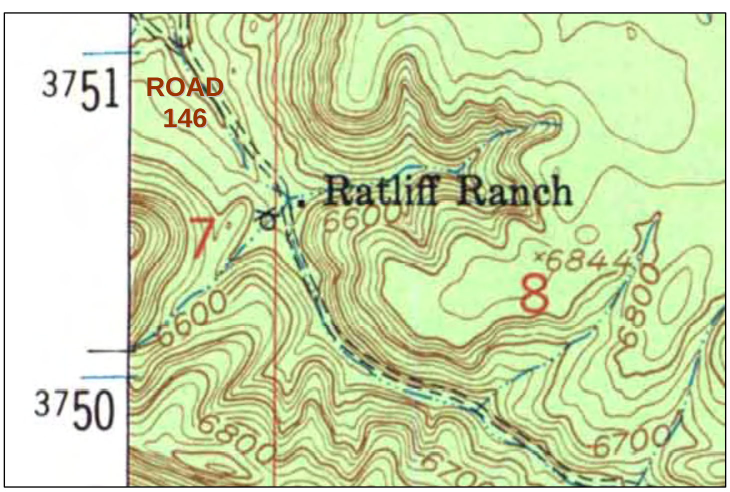


Fig. 10-17. USGS Topographic map excerpt showing the area around the Ratliff Ranch
(Broken Back Crater, N. Mex., 15-min.series, 1948. Contour interval = 25 ft)

Results of Off-Site Monitoring

Results of the off-site monitoring conducted by 44 individuals after the Trinity test are documented in handwritten notes, typed transcripts of these notes, and in summary forms (NTA 1946, Hempelmann 1947, Hoffman 1947, Lamont 1965, Maag and Rohrer 1982, Quinn 1987). Table 10-1 contains a summary of field team monitoring results recorded on 16-17 July 1945 that reached intensities of 100 mR h^{-1} or higher. After the trajectory of the cloud shifted toward the northeast, monitors focused mostly on areas along, or near, U. S. Route 380 to the east of Carthage and between Bingham and Carrizozo. Measured exposure rates first reached 100 mR h^{-1} at Searchlight Station L-8 around 7:30 a.m. Measurements in Bingham (30 km northeast of ground zero) reached 1.5 R h^{-1} by 8:25 a.m. and peaked at 3.3 R h^{-1} at 8:49 a.m. Gamma radiation levels in Adobe (5.4 km southeast of Bingham) were 6.5 R h^{-1} at 8:49 a.m. and fell to 1.6 R h^{-1} by 10:18 a.m. About 3 km farther southeast, in White Store, the highest recorded result was 3 R h^{-1} at 10:30 a.m.

The highest gamma intensities were found in the "Hot Canyon" area. Monitoring in the area of the canyon found gamma intensities up to "the vicinity of 20 R/hr" at 8:30 a.m. that dropped off to 6.0 R h^{-1} by 1:30 p.m. and 3.8 R h^{-1} by 1:57 p.m. (Hoffman 1946, NTA 1946, Hoffman 1947). Teams traveled north from the Bingham/L-8 area on Route 146 to monitor the Coker, Lucero, and Sedillo ranches. Gamma radiation above background was measured in the school yard at Vaughn [96 mi to the northeast of ground zero] 7.6 h after the blast, indicating that the cloud traveled no slower than 12.9 mi h^{-1} (Hoffman 1947). On the day after the blast, exposure rates as high as 300 mR h^{-1} were measured near Corona and Claunch, while exposure rates from 3 to 11 mi north of Vaughn ranged between 0.1 R h^{-1} and ">> 0.1" R h^{-1} shortly after 3:00 p.m.. At no location greater than 10 mi distant from ground zero was an alpha particle count obtained that could easily be distinguished from background with the instruments the monitors were using (Hoffman 1947).

At about 3:30 p.m. on the day of the blast, the recording G-M counter at Carrizozo began to track upward. About 15 min later, that meter went off scale on its least sensitive scale, and the monitor notified Base Camp by telephone (Hoffman 1946, Lamont 1965). Full scale on that recorder corresponded to 10,000 counts per minute ("cpm")(Hoffman 1947). After 1 h, the gamma intensity at Carrizozo was measurable on a single-scale Victoreen survey meter that indicated an intensity of 1.5 mR h^{-1} until the following morning (Hoffman 1946, NTA 1946). By 10:00 a.m., the G-M counter reading had decreased to 3,000 cpm.

Table 10-1. Exposure rates 0.1 R h^{-1} or greater measured 16-17 July 1945 near Trinity Site

Date and Time	Off-Site Location[a]	Recorded Exposure Rate (R h^{-1})
7:30 a.m.	Searchlight Station L-8	0.1
7:45 a.m.	11-16 km W of Carthage on US 380	0.2
8:00 a.m.	Searchlight Station L-8	0.5
8:25 a.m.	Bingham	1.5
8:25 to 9:15 a.m.	Searchlight Station L-8	2.0
8:29 a.m.	0.4 km W of Hansenburg Ranch	0.25
8:30 a.m.	Searchlight Station L-8	0.1
8:30 a.m.	5.6 km SE of L-8 ("Hot Canyon" area)	"vicinity of 20"
8:35 a.m.	Searchlight Station L-8	2
8:42 a.m.	1.6 km E of Bingham along US 380	1.0
8:45 a.m.	3.3 km W of Bingham	1.6
8:45 a.m.[c]	"Cooler spot" retreated to from 8:30 spot in canyon	15
8:46 a.m.	3.2 km E of Bingham along US 380	2.2
8:47 to 8:56 a.m.	From Searchlight Station L-8 to Hot Canyon	1.2 to 14.5
8:49 a.m.	Bingham	3.3
8:49 a.m.	6.4 km E of Bingham along US 380 (Adobe)	6.5
8:50 a.m.	4.8 km E of Searchlight Station L-8	15.0
8:50 a.m.	Hansenburg Ranch	0.45
8:56 to 9:40 a.m.	From Hot Canyon to Searchlight Station L-8	1.5 to 6.5
9:05 a.m.	4.8 E of Searchlight Station L-8	15.0
9:30 a.m.	Searchlight Station L-8	1.0
9:40 to 10:15 a.m.	N from L-8 to Rte. 41 cutoff to Maxwell Ranch	1.1 to 6.0
10:00 a.m.	0.8 km S of Hansenburg Ranch	0.8
10:15 to 10:50 a.m.	From Rte. 41 near Maxwell Ranch back to L-8	1.5 to 4.8
10:18 a.m.	6.4 km E of Bingham (Adobe)	1.6
10:22 a.m.	6.4 km E of Bingham along US 380	1.5
10:25 a.m.	9.7 km E of Bingham along US 380	3.0
10:25 a.m.	White Store	2.5
10:30 a.m.	White Store	3
10:30 to 11:30 a.m.	White Store	2.0
10:33 a.m.	8 km N of Bingham	0.5
10:40 a.m.	Just W of White Store on US 380	3.3
10:45 a.m.	8 km N of Bingham and 0.25 mi E (Wrye Ranch)	0.2
10:49 a.m.	Just W of White Store on US 380	3.2
10:54 a.m.	14 km E of Bingham along US 380	0.7
10:55 a.m.	0.8 km E of Bingham	1.3
11:00 a.m.	Bingham	1.55
11:00 a.m.	8 km E of Bingham	2.5
11:00 a.m.	6.4 km E of Bingham	2.0
11:00 a.m.	Bingham	0.5
11:30 a.m.	Bingham	1.7
11:40 a.m.	Bingham	0.65
11:50 a.m.	6.4 km W of Bingham	0.25
11:58 a.m.[c]	1.6 km W of Bingham	0.25
12:00 p.m.	Bingham	0.25
12:02 p.m.[c]	1.6 km E of Bingham along US 380	0.15

Date and Time	Off-Site Location[a]	As recorded[b] (R h^{-1})
Monday, July 16, 1945, continued (after blast at 5:30 a.m)		
1:00 p.m.	Bingham	1.5
1:27 p.m.	6.4 km E of Bingham along US 380	0.95
1:28 p.m.	0.2 km E of White Store on US 380	2.8
1:30 p.m.	White Store	0.15
1:30 p.m.	"Hot Canyon"	6.0
1:35 to 1:57 p.m.	1.6 to 4.8 km E of Searchlight Station L-8	0.5 to 3.8
1:47 p.m.	11 km E of Bingham along US 380	1.6
1:54 p.m.	2.4 km E of Bingham on US 380	1.5
2:00 p.m.	At Bingham	0.5
2:00 p.m.	Rte. 146 just E of junction with Rte. 161	6.0
2:13 p.m.	8 km N on Rte. 146 from junction Rte. 161	2
2:30 p.m.	6.4 km W of Bingham along US 380	0.16
2:30 p.m.	0.27 km E of Sedillo	0.27
2:30 p.m.	Coker Ranch	0.22
2:40 p.m.	9.7 km NE of Bingham on Rte. 161	3.5
2:46 p.m.	13 km NE of Bingham on Rte. 161	7
2:47 p.m.	0.27 km W of Coker Ranch	0.26
2:50 p.m.	Lucero Ranch	0.24
3:00 p.m.	S side of Rte. 161 near junction with Rte. 146	7.0
3:42 to 3:50 p.m.	11 to 21 km W of Vaughn on Rte. 60	"off scale"
4:30 p.m.	Cedarvale	0.11
4:48 p.m.[c]	1.6 km W of Cedarvale on Rte. 42	0.11
4:53 p.m.[c]	4 km mi W of Cedarvale on Rte. 42	0.15
4:59 p.m.[c]	7.2 km mi W of Cedarvale on Rte. 42	0.13
7:01 p.m.[c]	1.6 km E of Willard on Rte. 60	0.11
10:30 p.m.	White Store	0.25
Tuesday, July 17, 1945 (the day after the blast)		
11:39 to 11:54 a.m.[c]	25 to 39 km W of Corona toward Claunch	0.10 to 0.15
12:01 to 12:10 p.m.[c]	8 to 0 km E of Claunch on Rte. 42	0.11 to 0.18
12:14 to 12:21 p.m.[c]	3.2 to 9.7 km S of Claunch	0.11 to 0.19
12:26 to 12:54 p.m.[c]	14 to 40 km S of Claunch	0.11 to 0.30
1:05 to 1:09 p.m.[c]	9.7 to 5.6 km N of Bingham	0.11 to 0.18
2:00 p.m.	Bingham	0.10
3:00 p.m.	White Store	0.10
3:10 to 3:30 p.m.	4.8 to 18 km N of Vaughn on Rte. 285	0.1 to ">> 0.1"
3:30 p.m.	8 km N of Bingham on Rte. 41 toward Monte Prieto	0.19
3:30 to 4:02 p.m.	1.6 to 26 km N of Vaughn toward Encino	> 0.1
4:30 to 6:00 p.m.	24-40 km N of Bingham on Rte. 41 to Monte Prieto	0.19 to 0.30
5:50 to 6:36 p.m.	42-47 km E of Broadway (Trinity access) on US 380	0.11 to 0.5
6:30 p.m.	"Hot Canyon"	0.5
7:30 to 8:00 p.m.	8 to 0 km N of Claunch on road from Gran Quivira	0.10 to 0.19

[c] Measurement time estimated based on odometer readings and times specified for nearby measurements.

Evacuation Policy and Decision Making

Shortly before the Trinity blast, surface winds were blowing toward the North Shelter (Hoffman 1946). About 12 min after the shot, a "Watts' meter" at North Shelter indicated a rapid increase in radiation intensity because of a faulty zero setting (Hoffman 1946, Hoffman 1947, Maag and Rohrer 1982). When a remote ionization "sentinel" indicated a rapid increase in radiation, immediate evacuation of all personnel at that shelter was advised. Some personnel evacuated with such urgency that their cars were riding their hubs when they reached Base Camp 25 km south (Lamont 1965) While film badges worn by personnel in the shelter showed no exposures over 100 mR, the subsequent detection of radioactivity in the area was seen as evidence that part of the cloud had passed over but deposited little radioactivity on the ground (Maag and Rohrer 1982, Hacker 1987). Gamma intensities of 10 to 20 mR h^{-1} were measured around North Shelter 2 h after evacuation (Bainbridge 1976).

Most of the Army evacuation detachment and five radiological safety monitors that were stationed near Guard Post 2 northwest of ground zero remained there until a platoon was sent to Bingham while monitors surveyed that area (Maag and Rohrer 1982). When the chief monitor learned of the exposure rates as high as 3.3 R h^{-1} at Bingham, Adobe, and White Store, he projected that total exposures in that region might approach the allowed limit. The exposure rate of 6.5 R h^{-1} taken 4 mi east of Bingham at 8:49 a.m. was judged to be "getting close to the evacuation limit."[i] A message was sent by courier to Base Camp that integrated gamma doses had been projected at 90% of tolerance (Hoffman 1947, Hacker 1987). Medical experts were summoned, exposure rates decreased as the dust dispersed and settled, and no evacuation of the area was conducted. The evacuation detachment was dismissed at 1:00 p.m. on shot day "when it became evident that evacuations would not be undertaken" (Maag and Rohrer 1982).

After the recording beta-gamma meter at Carrizozo went off scale around 4:20 p.m. on test day, scientists and military officials considered whether Carrizozo should be evacuated. They held off taking that action for some additional monitoring and within an hour, fallout readings dropped, it was concluded that the radioactive cloud had passed over, and no evacuation was ordered (Hoffman 1946, NTA 1946, Lamont 1965, Hacker 1987). As the cloud drifted beyond the 15 mi radius, such as north of Bingham and around Carrizozo, monitors often overreached the limits of radio communication with Base Camp (Bainbridge 1976). As officials at Base Camp were advising Washington that the danger from radioactive fallout was diminishing, they were out of communication with monitors that were measuring fallout in areas as distant as 112 mi to the north (Lamont 1965).

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[i] Notes taken by radiation monitors Robert R. Leonard and W.J. McElwreath, 16 July 1945. LANL Archives Collection A-84-019, Box 8 Folder 1.

Historical records indicate that pressures to maintain secrecy and avoid legal claims led to decisions that would not likely have been made in later tests. Even though exposure rates, total exposures, and alpha count rates exceeding pre-established limits were measured and projected; a “cover story” was in place that would have provided an avenue for relatively inconspicuous evacuation of selected residents; and evacuation personnel, vehicles, shelters, and supplies were on standby, no evacuations of members of the public were conducted.

In a July 31, 1945 War Department memorandum to Dr. Louis Hempelmann (reproduced in Hempelmann 1947), Lt. Daniel Dailey of the Corps of Engineers refers to requests from Hempelmann that “the health of persons in a certain house near Bingham, N.M. be discretely investigated.” Over the 2 y following Trinity, at least seven visits were made to the Ratliff ranch by LANL and MED medical personnel, health physicists, and Army Intelligence agents, “under suitable pretext,” to check on the visible condition of the residents (Hempelmann 1947, Hoffman 1947). Even after the atomic bombs were dropped, the atomic bomb project and the roles of Los Alamos and Trinity were described publicly, and the need for secrecy diminished, the reasons for these visits were not disclosed to the residents.

Monitoring practices and protective action decision processes after the Trinity blast were clearly focused on the immediate hazards of radiation exposure. In the health physics community of the MED “the thinking had not yet focused on possible long-term effects” (Pierre 1972, Hacker 1987, Stannard 1988). Medical surveillance of ranchers was limited to casual observation of external appearances and veiled, nonspecific questioning regarding any health complaints. Although concern was voiced for the health status of at least one family, no evidence was found of steps being taken to reduce exposures to ranchers who continued to live in the fallout zone after July 1945. This was in spite of the fact that soil and the grasses eaten by grazing livestock were particularly radioactive in the area of Hot Canyon. In retrospect, Hempelmann acknowledged that “a few people were probably overexposed, but they couldn’t prove it and we couldn’t prove it. So we just assumed we got away with it.” (Hempelmann and Henrickson 1986)

After the Trinity test, Los Alamos scientists estimated effective rates of decay and total (external) doses delivered for several public areas (Hoffman 1947). LASL scientists defined the “geometrical dose” as the integrated dose under the maximum exposure rate that preceded the steady decay (Hoffman 1947). The geometrical dose was seen to represent “high intensity, short duration dose” that “can be a severe health hazard because it is delivered in a short time interval.” The integrated dose used by Los Alamos scientists in 1945 did not include the area under the maximum, but corresponded to the “long, low intensity decay that follows [the maximum]” out to a point in time 14 d after the blast (Hoffman 1947). The maximum tolerable values of geometrical dose and integrated gamma ray dose for the entire body over a period of 14 d were 50 and 75 R, respectively (Hoffman 1947).

Table 10-2 shows the geometrical doses, integrated doses, and total doses (geometrical plus integrated) that were reported by Hoffman (1947) for Hot Canyon, White Store, and Bingham. Correction factors for shielding by house structures were based on measurements in Los Alamos (wooden frame) and Bingham (adobe) houses on 19 July and 17 August 1945, respectively (Hoffman 1947). Based on monitoring done on and beyond the day after the blast, Los Alamos scientists estimated doses at the Ratliff residence (Hempelmann 1947). For the first 14 d after the blast, the geometrical dose was estimated to be 15 R, the dose from the ground 32 R, and the total accumulated dose (waist high) 47 R– said to be a factor of 33 above the tolerance. Radioactivity at the nearby Wilson ranch was estimated to be 75% of that at the Ratliff ranch (Hempelmann 1947).

Table 10-2. External gamma ray exposure values calculated for several public areas after the Trinity test by Los Alamos scientists (Hoffman 1947)

Location	"Geometrical Dose" (R)	"Integrated Dose" (R)	"Total Dose" after 14 d (R)
"Hot Canyon"			
On the ground[a]	24	115	139
Corrected for house shielding[b]	24	62	88
Corrected to torso level[c]	15	41	56
Torso level, no house shielding[d]	28	76	100
White Store			
On the ground	8.4	21.8	30.2
Corrected for house shielding	8.4	11.8	20.2
Corrected to torso level	4.2	5.8	10
Torso level, no house shielding	7.8	10.7	19
Bingham			
On the ground	3.3	24	27.3
Corrected for house shielding	3.3	0.3	17.3
Corrected to torso level	1.7	6.5	8.1
Torso level, no house shielding	3.1	12	15

[a] Estimated at 10 cm above the ground surface.
[b] Gamma dose reduced by 46% to account for shielding by an adobe house.
[c] Dose at torso level estimated to 50% of the dose at 10 cm above ground level during the 2 weeks.
[d] "Corrected to torso level" values divided by 0.54 to estimate torso level with no house shielding..

Assessments of Trinity Fallout Performed by Others

Exposure rate contour lines based on the data collected by the town monitoring crews in 1945 based on modeling by the Weather Service Nuclear Support Office (Quinn 1987) and extended by Lawrence Livermore National laboratory (Cederwall and Peterson 1990) are presented in Figures 10-18 and 10-19. The lines in Fig. 10-18 that extend roughly east-west at five distances from ground zero indicate approximate locations of the edge of the cloud at times from 2 to 14 h after the shot. The extensions of the fallout contours in Fig. 10-19 show the contamination leaving New Mexico into Colorado and the northwest portion of Oklahoma.

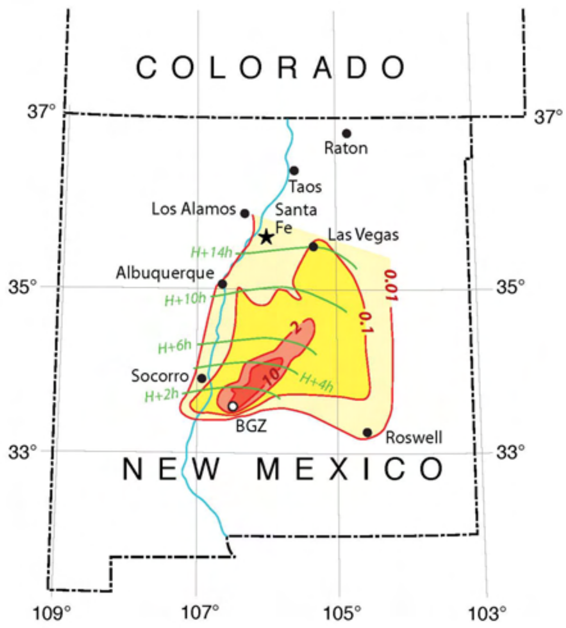

Fig. 10-18. The 0.01, 0.1, 2, and 10 R h^{-1} contours from the Trinity test at t + 1h, as analyzed by the Weather Service Nuclear Support Office (WSNSO, Quinn 1987). BGZ = ground zero.

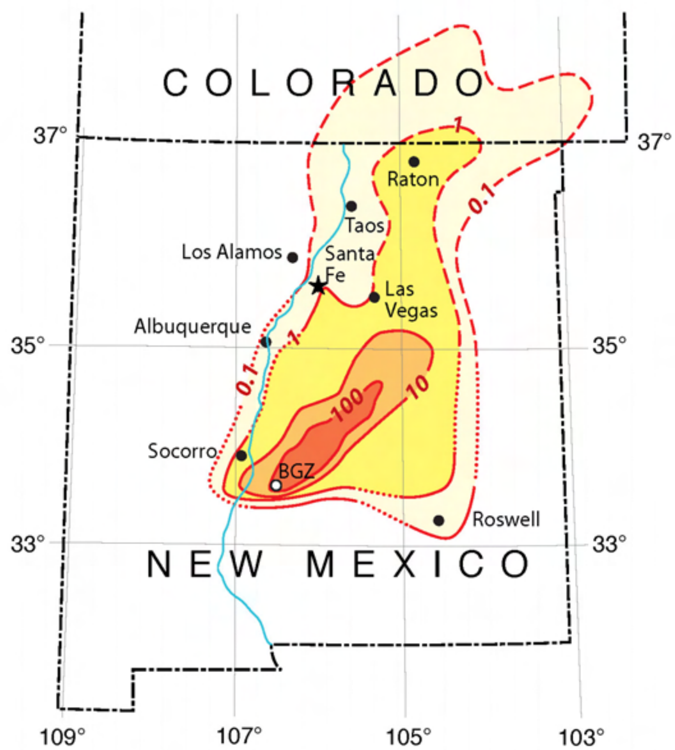

Fig. 10-19. Extension of Trinity fallout pattern as exposure rate, mR h-1 at t + 12 h, based on WSNSO analysis (Quinn 1987) extended (dotted lines) with LLNL modeling (Cederwall and Peterson 1990)

A source term for the Trinity event was calculated by scientists at Lawrence Livermore National Laboratory (Hicks 1985), and fallout patterns were reconstructed on behalf of the USDOE's Off-Site Radiation Exposure and Review Project (ORERP) (Quinn 1987). Unlike for the nuclear explosions at the Nevada Test Site, doses have not been reconstructed for the Trinity event, due primarily to scarcity of data (Anspaugh 2000).

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

Gaps in Information about the Trinity Test

In retrospect, pioneer health physicist J. Newell Stannard identified two main gaps in the description of Trinity event (Stannard 1988). The first deals with the characterization of residual plutonium, which was present due to the fact that the efficiency of the device was not 100 percent. The Trinity "Gadget" contained 6 kg of ^{239}Pu as its sole fissile material (USDOE 2001). The 21 kt yield of the blast (USDOE 2000) corresponds, at 1.45×10^{23} fissions per kt (Glasstone and Dolan 1977), to 3.05×10^{24} atoms or 1.21 kg of ^{239}Pu fissioned. That indicates that approximately 4.8 kg of ^{239}Pu remained unfissioned and was dispersed in the environment. It was present in the crater and partly scattered around the environment in the fallout. Monitors did find some plutonium— it was not measured very carefully near shot time, but its presence was hinted at in the initial surveys (Stannard 1988). The instruments used by field monitoring teams were acknowledged to be incapable of measuring alpha contamination in the environment to the desired sensitivities (Hoffman 1947). A full-scale survey of the Trinity site was not conducted until three years later, by a group from the UCLA medical school.

The second gap is the lack of any measures for detection of internally deposited radionuclides, such as bioassay, nose swabs, etc. At the time, nose swab collection and analysis was the main technique at Los Alamos of monitoring for inhalation of radioactive material, including in D Building where the plutonium hemispheres for the Trinity device were manufactured (Hempelmann and Langham 1953). There certainly were instances of inhalation of airborne radioactivity by members of the public who were in the path of the Trinity cloud or were near deposited radioactivity that was resuspended, and water and food products were also contaminated. For example, the Ratliff home in Hot Canyon used its tin roof to collect water into a cistern that served as the family's drinking water supply. This was a common practice in the area (Allen 2008). There was rain in the area the night after the shot, which means that deposited radioactivity was likely carried into their drinking water (Appendix II in Hoffman 1947).

Some Lessons about Off-site Impacts Learned from the Trinity Test

From the Trinity test, it was learned that detonating a nuclear explosive device close to the ground increases the radioactive fallout from the event. Detonating devices at higher elevations results in the dispersion of less radioactivity, while yielding more blast power. Based on experience with the Trinity event, and expanded upon in test series conducted in the Pacific during 1946 and 1948, the potential for exposure of workers and members of the public to fallout became known and appreciated (Anspaugh 2000).

It was also learned that "hot spots" are important phenomena when radioactive clouds disperse, and their occurrence can be influenced by local terrain features and air flow patterns.

The Trinity Site was judged to be too small for additional atomic tests to be conducted there. General Groves concluded that the Trinity test site "is too small for a repetition of a similar test of this magnitude except under very special conditions" (Hacker 1987). He proposed finding a larger site, "preferably with a radius of at least 150 miles without population" [compared to about 15 miles at Trinity] for any future test.

Follow-Up Studies of Trinity Fallout

After the Trinity blast, several monitoring teams continued through the remainder of 1945 to periodically traverse roads to the northeast of the site to measure and record exposure rates. Records of survey trips were found for excursions on 12 additional days in July, eight in August, two in November, and four in December (Hoffman 1946, NTA 1946, Hoffman 1947).

In August 1947, scientists from the University of California, working with Wright Langham from LANL, conducted a limited survey of a 26,000 ha (100 mi^2) area near the Trinity Site (Overstreet et al. 1947). Between 1949 and 1978, teams from UCLA and the U.S. Environmental Protection Agency (USEPA) published reports of studies of larger zones of local Trinity fallout (Warren and Bellamy 1949, Bellamy et al. 1951, Gillcoly et al. 1951, Leitch 1951, Nishita et al. 1957, Douglas 1978). The earliest UCLA surveys were limited to beta-gamma measurements. Measurements of gross alpha radioactivity in airborne particles (assumed to be plutonium) were first reported in 1951, as were alpha measurements of chemically separated plutonium from plants and soil. The first of these studies to include isotopic analyses of plutonium in environmental media (soil and air) was published by Douglas (1978) for samples collected in 1973 and 1974, over 28 y after the detonation.

Characteristics of members of the public near the Trinity Site

Population, ethnicity, diet, housing, and lifestyle characteristics of residents near the Trinity test site around 1945 were described based on, except where noted otherwise, interviews of current residents and historians (Allen 2008) and information from reviewed documents. Based on interviews of local residents and historians, the typical ethnic compositions of ranchers, sheepherders, and cowboys near the Trinity Site around 1945 were estimated to be as shown in Table 10-3. Both ranchers and people who lived in towns used the most readily available construction materials. As shown in Table 10-4, adobe was by the far the most common building material for homes and work places. Barn roofs were typically mud while home roofs were usually metal to facilitate water collection. In towns such as Carrizozo, most buildings were adobe, but homes made of wood frame construction and bricks were also present.

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Table 10-3. Estimated distribution of ethnicities for residents near the Trinity Site circa 1945 based on LAHDRA interviews (percentages)

Class of Persons	Anglo[a]	Spanish	Native American
Ranchers	90	10	0
Sheepherders	0	100	0
Cowboys	80	20	0

[a]Non-Hispanic white persons

Table 10-4. Estimated distribution of construction types for buildings near the Trinity Site circa 1945 based on LAHDRA interviews (percentages)

Building Type and Setting	Adobe	Wood	Stone	Brick
Ranch homes	85	10	10	0
Homes in towns	75	22	1	2
Ranch workplaces	80	15	5	0
Workplaces in towns	75	23	0	2

If it was daylight, ranchers and their hired hands were typically outside working. Breakfast would typically be eaten while it was still dark so work could begin at first light. Meals would have been eaten inside. Since the Trinity test occurred during the summer, children would also have been outside during daylight hours either working or playing. While ranch wives spent the bulk of their time outdoors tending to laundry, gardening, or helping with the livestock, wives typically spent more time inside than men preparing meals, canning food, and processing milk.

Cattle and sheep were commonly raised by ranchers in the area, and each ranch typically had horses, chickens, and a garden. Some ranchers also had hogs for their personal use. The Ratliff ranch maintained a herd of 200 goats and some turkeys and donkeys (Hempelmann 1947, Hoffman 1947). A long-time resident of the area indicated that these goats were raised for their hair, not their milk. If drought caused lack of forage, livestock was sold.

Ranchers and their hired hands had similar diets. Ranchers in the area typically collected rain water off metal roofs into cisterns, like shown in Fig.10-20, as their source of drinking water. Local ground water contained excessive mineral content that made it unsuitable for human consumption, but it was used to water livestock. Beans and potatoes were grown in vegetable gardens, but were often supplemented with purchases made in town. Flour, sugar, and other staples were bought in town. Produce, including peas, root crops, squash, and corn, was grown in gardens. Moreover, some ranchers had fruit trees. Produce that was not eaten fresh was canned in glass jars, with the goal to put up enough to take the family through to the next harvest. The primary fresh meat sources were deer and chickens, which also provided eggs. If the ranchers ate any beef, it was most likely from the grown calf from their dairy cow. Essentially all ranchers had a dairy cow, and ranch wives processed the milk to make other dairy products used on the ranches.

Fig. 10-20. A system for collection of water off the roof of a residence on the Black Hills Ranch, formerly the Nalda Ranch, east-northeast of the Trinity Site. The cistern to the left, which was damaged by the Trinity blast then repaired, is still in use today.

The ranches near the Trinity Site did not have electricity until after the war, but most had an icebox. Ice was purchased in town and stored underground at the ranch houses. Some ranchers might have had butane-powered refrigerators or coal-oil-powered refrigerators and stoves. Town dwellers bought their groceries, including milk products, from grocery stores. Town residents had electricity and refrigerators, and water was piped to their homes. Ranchers and historians have little knowledge of local ranchers who drank goat milk, except for one man who reportedly purchased goat milk in Belen, New Mexico. There has been no specific evidence found that indicates that the Ratliff family drank, sold, or shared goat milk.

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