AN ABSTRACT OF THE THESIS OF

R. Blair Bentley for the degree of Master of Science in Radiation Health Physics presented on April 28, 2008

Title: A Study of Residual Cesium 137 Contamination in Southwestern Utah Soil Following the Nuclear Weapons Tests at the Nevada Test Site in the 1950's and 1960's

Abstract approved:

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Kathryn Higley

The Nevada Test Site (NTS) was the location for at least 100 above ground Nuclear Weapons tests during the 1950's and early 1960's. Radioactive fallout from these tests spread to many areas north and west of the NTS. According to estimates from the NCI and DOE, Washington County, Utah was one of the areas which received some of the highest levels of radioactive contamination from Nuclear Fallout. Cesium 137, a byproduct of Nuclear Fission was one of the nuclides deposited during this fallout period. Cesium137 has a half life of 30 years and relatively high photon energy so it is easily detected and theoretically would still be present in the soil if it was originally deposited there. A study was conducted using soil samples from the Washington County area to determine if Cesium 137 still exists in the area in detectable amounts. 102 soil samples were

collected and analyzed. Only one of the 102 soil samples did not have detectable amounts of Cesium contained within it. Several of the samples contained levels substantially higher than earlier estimates would have predicted. This leads us to conclude that doses to the public from the testing could also have been higher than earlier thought. The area immediately around the community of Enterprise Utah contained the highest contamination readings of the locations we researched. Iron County, Northeast of St George, also had surprisingly high readings considering that the studies we researched stated that Iron County's contamination density was estimated to be lower than most of the areas in Washington County.

A Study of Residual Cesium 137 Contamination in Southwestern Utah Soil Following the Nuclear Weapons Tests at the Nevada Test Site in the 1950's and 1960's

by

R. Blair Bentley

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APPROVED:

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Major Professor, representing Radiation Health Physics

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Head of the Department of Nuclear Engineering and Radiation Health Physics

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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R. Blair Bentley, Author

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Introduction

The United States of America Conducted 100 above ground nuclear weapons tests at the Nevada Test Site (NTS) during the 1950s and early 1960s.(Simon et al 2006) Similar tests were conducted in other parts of the world by Great Britain, France and most notably the Soviet Union. In 1963, a treaty was signed by these countries eliminating above ground testing, although underground tests continued for many years afterwards.

Many communities located downwind from the NTS, particularly those in Eastern Nevada, Southwest Utah and Northwest Arizona received substantial radiation doses from the fallout of those nuclear tests. People living in those areas at that time reported watching the fallout cloud drift overhead and having their cars covered with grey dust the morning after a test was completed. Government officials assured people everything was safe and radiation doses received from the testing were minimal. (Wasserman, et al 1982)

However, subsequent studies have predicted that some areas were in fact exposed to high doses of radioactive fallout, and particularly children may have received dangerous levels of radioactivity from drinking milk contaminated with radioactive iodine. (Committee 1999)

Concern and distrust still exists among the cities and towns who were affected by the nuclear weapons testing. People still believe the levels of contamination were much higher than even current reports predict and that a government cover-up conspiracy still exists in regards to radioactive contamination. (Salzman1986)

Many of the radioactive byproducts of nuclear weapons testing are short-lived substances that have since decayed down to background, and we will never truly know the amount of radioactive contamination that existed at the time of the testing. However, some of the products do have long half-lives and should still exist in measurable levels if they were ever deposited here during the weapons testing (Beck1999).

One of the common products of nuclear fission is Cs137. It only exists in a man made state either as a by-product of a nuclear explosion, or as a radionuclide produced in a nuclear reactor and used for either medical or industrial purposes. (U.S. EPA 2002) Cs 137 has a half-life of 30 years and emits a gamma photon with an energy level of 662 keV. These qualities allow researchers to measure it easily because its high energy level enables it to be detected from under the soil. Its long half-life keeps it around in the environment for an extended period of time. These qualities also allow researchers to make assumptions concerning the amount of cesium that existed during at the time of the testing. It has been well over 50 years since the majority of the nuclear weapons testing were being conducted. Given that cesium has a 30-year half-life, after 60 years, there would be about 25 percent of the original deposited radioactivity in the surrounding soil without taking into account erosion or seepage into the ground. It can therefore be assumed that nearly 4 times the measured amount today, existed in the soil shortly after the testing was complete. Several estimates show that cesium was assumed to have spread in a wide area west of the NTS. Eastern Nevada and Washington County Utah were thought to have received some of the highest levels in the United States (see figure 2.) As shown, over 700Bq /m^2 of Cesium 137 were estimated to have fallen on Washington county during the above ground weapons testing period. (Sublette2001)

What has happened to this cesium in the past 50+ years? Is it still around in measurable quantities, or has it decayed and eroded away? Is there enough contamination remaining in the soil in some areas to present health risks to people living here? Are there areas in the county where the concentrations are significantly higher than others?

The purpose of this paper is to answer some of these questions in a simple and non-partisan way. The downwinders issue is so volatile that it is difficult sometimes to find articles on it that are not strongly slanted one way or the other. Government studies are generally dismissed as lies by members of local communities because of the inherent distrust that remains in the wake of how the dangers of the original testing were hidden from the people until long after the testing was completed. (Salzman1986)

Studies completed by interest groups and the anti-nuclear communities are dismissed as unpatriotic, biased and non-scientific because they are usually trying to prove a preconceived point and are often based on anecdotal and non-provable information. (Wasserman1982)

This paper will simply present the results of soil sample measurements throughout Southwestern Utah in an attempt learn the truth concerning Cs137 contamination levels in the soil. These individual measurements will be compared with each other to see if patterns exist in contamination levels, and with other studies to either solidify or contradict their results.

Literature Review

The literature review is organized into the following sections (1) Physical properties of Cesium 137; (2) History of the Nevada Test Site and the weapons testing that occurred there; (3) Government studies estimating the amount of contamination deposited by the weapons tests and the subsequent radiation doses to the public; (4) Data collected from soil sample studies after the above ground testing was completed. (5) Dose estimates and contamination data from "downwinder" anti-nuclear groups.

<u>Physical Properties of Cesium 137</u>

Cesium-137 and its decay product, barium 137m are produced spontaneously when other radioactive materials such as uranium and plutonium absorb neutrons and undergo fission.(US EPA 2002) It commonly occurs during fission reactions in reactors or in nuclear weapon explosions.

Cesium 137 decays in the environment by emitting beta particles. It decays to barium-137m- a short-lived decay product that emits gamma radiation of moderate energy (662 keV) and then decays to a stable form of barium.

Cesium-137 is significant because of its prevalence, because it has a relatively long half-life, (30 years), and because of its potential harmful effects on human health.

People can be exposed to Cesium-137 externally by being in close proximity to a cesium source or by inhaling or swallowing it. When it enters the body, it is usually distributed fairly evenly throughout the body- a little more in the muscles, a little less in the bones and fat. It remains in the body for a relatively short time, and is eliminated quicker by infants and children than by adults.

Based on experimentation with ionization radiation and human epidemiology, exposure to radiation from Cesium 137 can result in malignant tumors and shortening of life. It is estimated that there will be over 1000 additional cancers over the next 70 years among the population of Western Europe who were exposed to fallout from the Nuclear Reactor accident at Chernobyl (National Radiological Protection Board of Great Britain)

The EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta and photon radioactivity from manmade sources in drinking water. The average concentration of Cesium-137 that is assumed to yield that level is 200 picocuries/liter of water. This converts to about 7.4 Becquerels (Bq) per liter. (U.S. EPA 2000)

The EPA in a Record of Decision concerning the cleaning up of radioactive contaminants in the soil within the Oak Ridge National Laboratory boundaries required that cesium levels in areas where workers may be mowing grass or otherwise taking care of the grounds needed to be below 120 pCi/gm or 4.4 Bq/gm (EPA Superfund 1993)

History of the above ground testing at the Nevada Test Site (NTS)

The Nevada Test Site (NTS) is a United States Department of Energy reservation located in Nye County, Nevada. It is located about 65 miles northwest of Las Vegas. It was originally know as the Nevada Proving Ground and was established on Jan. 11, 1951 for the purpose of testing nuclear weapons. It is made up of nearly 1350 square miles of desert and mountains. (Wikipedia 2007)

The first Nuclear weapon test at the NTS occurred on January 27th 1951. Over the next 11 years, 100 above ground tests were conducted at the site. Over 800 announced underground tests have also occurred since that time. Seismic data suggests that there were several unannounced tests occurring that same time period. The site is now covered with subsidence craters from the testing. The

Nevada Test Site was the primary testing location of American nuclear devices; only 129 tests were conducted elsewhere (many at the Pacific Proving Grounds in the Marshall Islands).

During the 1950s, the mushroom clouds from these tests could be seen for almost 100 miles in either direction, including the city of Las Vegas, where the tests became tourist attractions. Americans often headed for Las Vegas to witness the distant mushroom clouds that could be seen from the downtown hotels.

On July 17, 1962 the test shot "Little Feller I" of Operation Sunbeam became the last atmospheric test detonation at the Nevada Test Site. Underground testing of weapons continued until September 23, 1992, and although the United States did not ratify the Comprehensive Test Ban Treaty, the articles of the treaty are being honored and further tests have not occurred. Tests not involving the full creation of a critical mass ("subcritical" testing) continue. Many of these tests involve the detonation of explosives to test the strength of nuclear material storage containers, or to determine the spread of radioactivity in a “dirty bomb” type scenario when someone blows up non critical quantities of radioactive material in a populated area in an attempt to create fear and panic.

One notable test shot was the "Sedan" shot of Operation Storax, a 104 kiloton shot for the Operation Plowshare which sought to prove that nuclear weapons could be used for peaceful means in creating bays or canals—it created a crater 1,280 feet (390 m) wide and 320 feet (100 m) deep that can still be seen today.

There are currently tours being conducted on the Nevada Test Site which take you to the edge and allow you to see the size of this manmade crater. While many of the larger tests were conducted elsewhere, NTS was home to tests in the 500 kiloton to 1 megaton (2 to 4 petajoule) range, which caused noticeable seismic effects in Las Vegas.

The site was recently scheduled to be used to conduct the testing of an 1100-ton conventional explosive in an operation known as Divine Strake in June 2006. The bomb is a possible alternative to nuclear bunker busters, which Congress has been reluctant to fund, despite support from President Bush. However, after objection from Nevada and Utah members of Congress, the operation was postponed until 2007. On 22 February 2007 the Defense Threat Reduction Agency (DTRA) officially canceled the experiment.

As of 2004, the test site offers public tours on approximately a monthly basis, although the taking of souvenir material is prohibited. (Doesn't everyone want to take a little radioactive dirt home with us to put in their trophy case?) Additionally, image taking and communication devices are prohibited.

The site is also the location of the Area 5 Radioactive Waste Management Complex, which sorts and stores low-level radioactive waste that is not transuranic and has a half life of no greater than 20 years. Bechtel runs this complex.

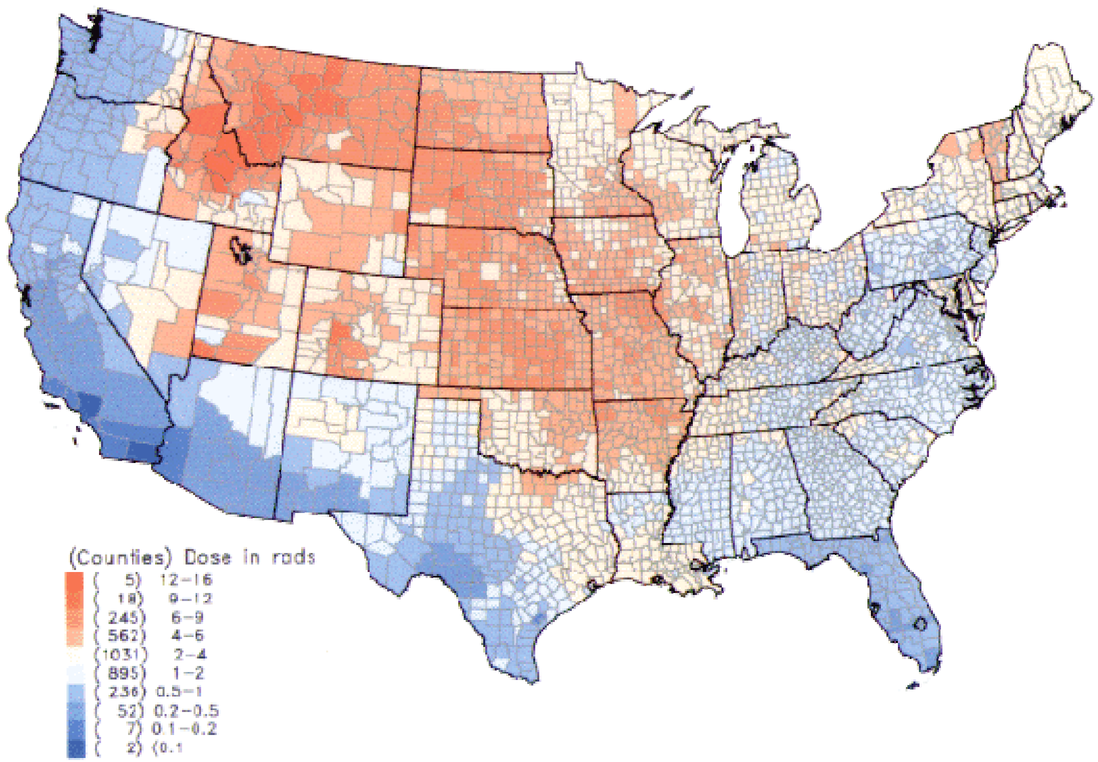
Located at the ground zero for the Operation Teapot nuclear test is also the Transportation Incident Exercise Site, which replicates multiple terrorist radiological incidents with train, plane, automobile, truck, and helicopter props.

The town of Mercury, Nevada is located on the grounds of the NTS, and at one time housed contingents from Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories. Area 51 and

the proposed high-level nuclear waste storage facility at Yucca Mountain are located nearby. The BREN Tower, a 465 meter high guyed tower was originally used for radiation experiments with an unshielded reactor simulating the amounts of radiation received by survivors from Hiroshima and Nagasaki. It is located in the center of the NTS at Jackass Flats.

In a report by the Department of Health and National Cancer Institute, released in 2001, it was determined that ninety of the atmospheric tests at the Nevada Test Site (NTS) deposited high levels of radioactive iodine-131 (5.5 hexabecquerels) across a large portion of the contiguous United States, especially in the years 1952, 1953, 1955, and 1957—doses large enough, they determined, to produce 10,000 to 75,000 cases of thyroid cancer. The map below shows areas in the United State that received iodine contamination from the above ground nuclear weapons testing. (Map courtesy of the NCI study of 1997) Washington County is the most southwestern county in Utah. It appears to have received a higher dose of iodine than most of its surrounding counties.

Figure 1. Radiation Contamination Dose Estimate for the United States from the Above Ground Testing at the Nevada Test Site (figure courtesy of NCI and Harold L Beck)



The Radiation Exposure Compensation Act of 1990 allowed for people living downwind of NTS for at least two years in particular Nevada, Arizona or Utah counties, between January 21, 1951 – October 31, 1958 or June 30, 1962 – July 31, 1962, and suffering from certain cancers or other serious illnesses deemed to have been caused by fallout exposure to receive compensation of $50,000. This act was amended in the year 2000 to include more types of cancer and a larger geographic area. (Office of Senator Orrin Hatch, 2000) By January 1 2006, over 10,500 claims had been approved, and around 3,000 denied, for a total amount of over $525 million in compensation dispensed to "downwinders"

Uranium miners, mill workers and ore transporters are also eligible for $100,000 compassionate payment under the Radiation Exposure Compensation Program, while $75,000 is the fixed payment amount for workers who were participants in the above-ground nuclear weapons tests.

Table1. Below is a list of the different weapons testing operations that were conducted on the Nevada Test Site: Each operation usually involved several different nuclear tests.(courtesy of Nevada Test Site and US Department of Energy.)

Operation Ranger — 1951

Operation Buster-Jangle — 1951

Operation Tumbler-Snapper — 1952

Operation Upshot-Knothole — 1953

Operation Teapot — 1955

Project 56 — 1955

Operation Plumbbob — 1957

Project 57, 58, 58A — 1957–1958

Operation Hardtack II — 1958

Operation Nougat — 1961–1962

Operation Plowshare — 1961–1973(sporatic, at least one test a year)

Operation Grommet — 1971–1972

Operation Arbor — 1973–197

Operation Toggle — 1972–1973

Operation Bedrock — 1974–1975

Operation Anvil — 1975–1976

Operation Fulcrum — 1976–1977

Operation Crescent — 1977–1978

Operation Quicksilver — 1978–1979

Operation Tinderbox — 1979–1980

Operation Guardian — 1980–1981

Operation Praetorian — 1981–1982

Operation Sunbeam — 1962

Operation Dominic II — 1962–1963

Operation Storax — 1963

Operation Niblick — 1963–1964

Operation Whetstone — 1964–1965

Operation Flintlock — 1965–1966

Operation Latchkey — 1966–1967

Operation Crosstie — 1967–1968

Operation Bowline — 1968–1969

Operation Mandrel — 1969–1970

Operation Emery — 1970

Operation Phalanx — 1982–1983

Operation Fusileer — 1983–1984

Operation Grenadier — 1984–1985

Operation Charioteer — 1985–1986

Operation Musketeer — 1986–1987

Operation Touchstone — 1987–1988

Operation Cornerstone — 1988–1989

Operation Aqueduct — 1989–1990

Operation Sculpin — 1990–1991

Operation Julin — 1991–1992

There are several other sources of information concerning the above ground testing at the NTS. The following are excerpts from an additional source entitled the Gallery of U. S. Nuclear Tests.(Sublette,2001)

Between 16 July 1945 and 23 September 1992 the United States of America conducted (by official count) 1054 nuclear tests, and two nuclear attacks. (Nuclear Weapon Archive 2001)The number of actual nuclear *devices* (aka "bombs") tested, and nuclear *explosions* is larger than this, but harder to establish precisely. Some devices that were tested failed to produce any noticeable explosion (some by design, some not), other "tests" (by official definition) were actually multiple device detonations. It is not clear whether all multiple device tests have yet been identified, and numbered. These pages focus principally (although not exclusively) on the period from 16 July 1945 to 4 November 1962, the era of atmospheric testing*. There are a number of reasons for this. These early years marked the height of the Cold War, when the U.S. nuclear weapons establishment came into being, when the major breakthroughs in weapon design occurred, and when the most severe effects of nuclear testing were felt around the world. During this period test series were grand operations, involving huge numbers of people, and each often with a set of clear objectives. The era of atmospheric testing is also the period for which the most information is available. When tests were exploded in the open, everyone could collect data on what was being tested. When the tests went underground, testing became routine, and information about what was being tested went underground too.

There were actually a few surface tests included in the official test count conducted after 4 November 1962. These were a series of zero yield tests of plutonium dispersal conducted in 1963, known as Operation Roller Coaster. Ever since nuclear testing began, it has been very difficult to get a useful accounting of human exposures to the fallout from these tests. Partly this was motivated by military secrecy, partly by a desire to allay public fears (i.e. public relations reasons), and partly by a fear of possible legal action by actual of potential victims. Some exposure related incidents have been revealed due to the impossibility of hiding them: namely the high radiation exposures of the Marshallese and the Japanese aboard the *Fifth Lucky Dragon* after the Castle

Bravo disaster. But most information on this subject has been withheld, deliberated buried in obscure reports, or never collected. (This is the principle of being careful not to learn what you don't want to know). This information has slowly come to light in bits and pieces over the last 20 years.

What is probably the most important study of the health effects of nuclear weapons testing was announced by the National Cancer Institute in August of 1997, and released in October. The study report is now available on line: National Cancer Institute Study Estimating Thyroid Doses of I-131 Received by Americans from Nevada Atmospheric Nuclear Bomb Test. The basic finding of the report was that internal exposures to radioiodine (I-131) in fallout from continental nuclear testing was the most serious health consequence from the above ground weapons testing. Radioiodine concentrates in milk when consumed by cows when grazing, and then concentrates in human thyroid glands when contaminated milk is ingested. This concentration effect is especially strong in children. The NCI study estimates that the average American alive at the time of the nuclear weapons testing received a thyroid radiation exposure of 2 rads, with some people receiving up to 300 rads. The effect of these exposures is to boost the chance of contracting thyroid cancer some time during a lifetime. This cancer is normally not very rare, and is highly treatable (as cancers go). It is possible to estimate the overall effect of the total radiation exposure of the American population. From the 380 million person-rads of total exposure roughly 120,000 extra cases of thyroid cancer can be expected to develop, resulting in some 6,000 deaths. For comparison, the worst industrial disaster in history (Bhopal, India; 3 December 1984) killed about 3000 people and injured 150,000. No effort was made to systematically study the nationwide effects of atmospheric nuclear testing until congress ordered the study -- which was finally released *15* years later. In a hearing held in September 1998, Bruce Wachholz, chief of the radiation effects branch of the National Cancer Institute, told a Senate hearing that

the basic results were known as early as 1989 and a final draft report was completed in 1992 yet none of the information was made public for five more years. United States nuclear tests were conducted on an intermittent basis from July 1946 to October 1958. During this period, nuclear tests were conducted in groups known as "operations" or "test series", each series was a distinct operation that was organized and carried out independently of other operations. On 31 October 1958, just after it concluded the largest test series to date, the United States entered into a unilateral testing moratorium announced by President Eisenhower with the understanding that the former Soviet Union also would refrain from conducting tests. The Soviet Union honored this moratorium initially, but secretly prepared for a massive testing campaign, which commenced in September 1961, and included the largest nuclear tests ever conducted.

On September 15, 1961, the United States resumed testing at the Nevada Test Site (NTS) on a year-round basis with Operation Nougat. From that time to the present, tests have principally been grouped for fiscal and reporting purposes into "operations" or "series" according to the fiscal year in which they took place.

For example, fiscal year 1963 tests -- which began 1 July 1962 and extended through 30 June 1963 -- were in the Operation Storax series. Atmospheric testing concluded with the test Dominic/Fishbowl Tightrope on 4 November 1962. The signing of the Atmospheric Test Ban Treaty on 5 August 1963 in Moscow halted all further atmospheric testing by both superpowers. The Fiscal Year based underground series was perturbed in 1976, when the federal government changed the fiscal year to begin on October 1 and end on September 30. Accordingly, the Fiscal Year 1976 series, Operation Anvil, did not end on June 30, but was extended through September 30, 1976 -- a period of 15 months.

On March 31, 1976, the Soviet Union and the United States agreed to limit the maximum yield of underground tests to 150 kt. On October 2, 1992, the United States entered into another unilateral moratorium on nuclear weapons testing announced by President Bush. President Clinton extended this moratorium in July 1993, and again in March 1994 until September 1995. With the signing of the Comprehensive Test Ban Treaty in September 1996, the United States -- along with the other nuclear powers -- made a legal commitment never to test nuclear devices again, even though this treaty will likely never go into force due to the opposition of India.

Table 2. Below is a list of all nuclear testing operations conducted by the United States Government throughout the world. The number of actual tests per operation is denoted on this figure. (Courtesy of Corey Sublette and "The Gallery of Nuclear Tests)

The Atmospheric Test Series

Trinity - The First Nuclear Test

Operation	Year	Location	Number
Trinity	1945	Alamagordo New Mexico	1

The Post War Test Series

Operation	Year	Location	Number
Crossroads	1946	Bikini Atoll	2
Sandstone	1948	Enewetak Atoll	3
Ranger	1951	Nevada Test Site	5
Greenhouse	1951	Enewetak Atoll	4
Buster-Jangle	1951	Nevada Test Site	7
Tumbler-Snapper	1951	Nevada Test Site	7
Ivy	1952	Enewetak Atoll	2
Upshot-Knothole	1953	Nevada Test Site	11
Castle	1954	Bikini Atoll Enewetak Atoll	6
Teapot	1955	Nevada Test Site	14
Wigwam	1955	Pacific Ocean	1
Project 56	1955	Nevada Test Site	4
Redwing	1956	Bikini Atoll Enewetak Atoll	17
Plumbbob	1957	Nevada Test Site	30
Project 58	1957	Nevada Test Site	2
Project 58 A	1958	Nevada Test Site	2

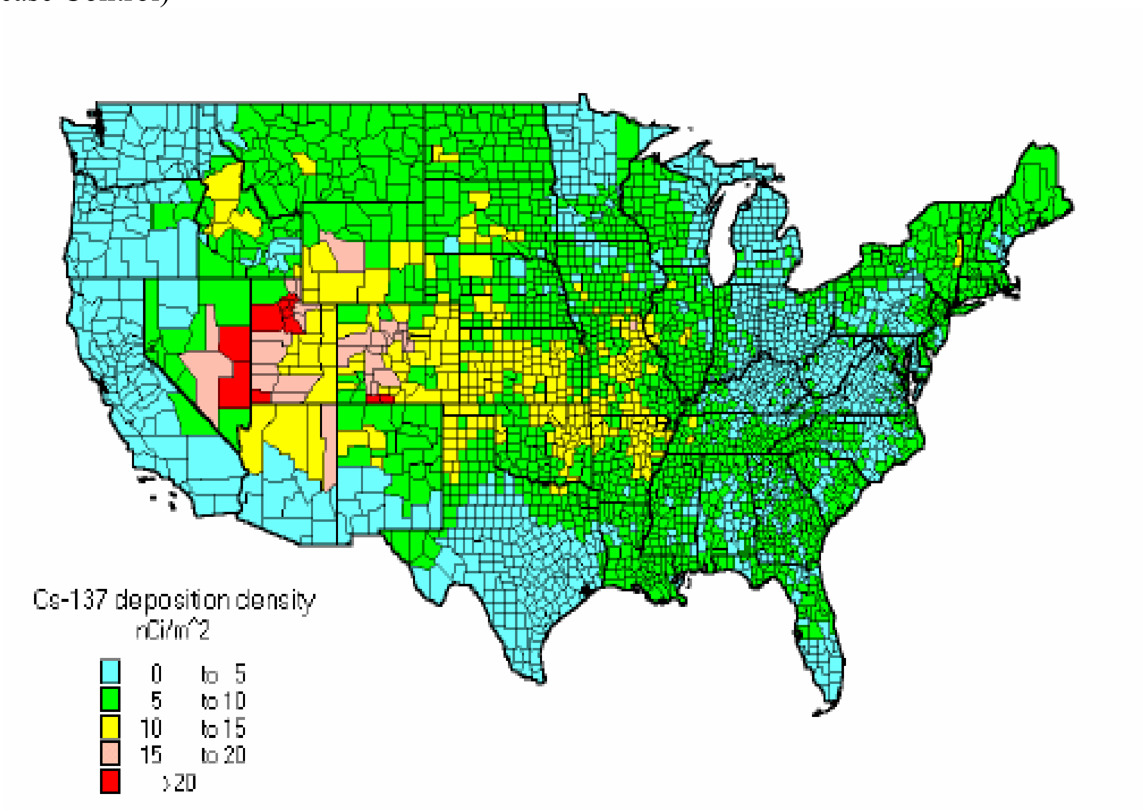
Hardtack I	1958	Bikini Atoll Enewetak Atoll Johnston Island	35
Argus	1958	South Atlantic	3
Hardtack II	1958	Nevada Test Site	37
Nougat	1961-1962	Nevada Test Site	32
Dominic (with Fishbowl)	1962	Christmas Island Johnston Island Central Pacific	36
Storax (with Sunbeam and Roller Coaster)	1962-1963	Nevada Test Site Nellis Air Force Range	56

Since July 1962, all nuclear tests conducted in the United States have been underground, and most of them have been at the NTS. Some tests were conducted on the Nellis Air Force Range (NAFR); in central and northwestern Nevada; in Colorado, New Mexico, and Mississippi; and on Amchitka, one of the Aleutian Islands off the coast of Alaska.

Government funded studies showing dose estimates and measurement .

The United States Department of Energy has conducted studies to determine contamination dose levels from the nuclear weapons tests conducted at the NTS. The results of some of those studies are as follows: June, 1999- A report was presented to the National Cancer Institute by Harold L. Beck, in response to a request by Congress, the NCI and CDC attempting to determine the radiation exposure to the population of the Continental United States, as a result of the above ground nuclear testing at the NTS and how that exposure might affect overall health of the people living downwind from the testing. (Dept of Health and Human Services et al 2001) This reports estimated that Washington County was exposed to more than 20 nCi/m2 (see diagram) of cesium 137 during all of the testing. Iron and Kane counties were estimated to have received 15-20 nCi/m2 and Northern Arizona, only 10-15 nCi/m2.(20 nanocuries is about the equivalent of about 740 Becquerel). Maps showing cesium and other nuclide levels were presented and estimates were made regarding contamination from testing both at the NTS and worldwide.

(see map below)
Figure 2. Cesium137 Deposition Density in the United States from the Weapons Testing at the Nevada Test Site. (courtesy of Harold Beck and the Centers for Disease Control)



Note- 20 nCi is the equivalent of 740 bcq.

Many different types of nuclides were created and deposited on the earth as a result of the nuclear weapons testing. Cesium made up a very small fraction of the total fallout yield from each of these tests (about .05 percent). (See Table 3 below) However because most of the fission products have either decayed away, (see Figure 3 below) or emit gamma, beta or alpha particles that are low in energy or otherwise difficult to detect, it is useful to study and track cesium contamination in estimating past doses because its long half life allows us to predict levels that were present 50-60 years ago during the testing.

Table 3: Total deposition of selected radionuclides for NTS fallout (courtesy of Harold Beck and the Centers for Disease Control)

Radionuclide	KCi Deposited
Cs-137	62.5 `
Sr-90	49.2
Zr-95	5900
Ru-103	11500
Ba-140	37600
Ce-141	13500
Ce-144	1070
Ru-106	635
Sr-89	9000
I-131	40100
Pu-239+240	3.6#
Pu-241	14.6

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Figure 3. The Chart below shows fallout nuclides and their individual half lives. Note that most of the nuclides decay in a matter of days instead of years. (taken from American Scientist Magazine

		Nevada Test Site fallout			global fallout		
radionuclide	half-life	thyroid or red bone marrow external dose (mGy)	thyroid internal dose (mGy)	red bone marrow internal dose (mGy)	thyroid or red bone marrow external dose (mGy)	thyroid internal dose (mGy)	red bone marrow internal dose (mGy)
carbon-14	5730 y	-	-	-	-	0.1	0.1
cesium-137	30 y	0.01	0.009	0.009	0.3	0.1	0.1
strontium-90	28.5 y	-	-	0.02	-	0.0009 [0.002][a]	0.2 [0.5][a]
tritium	12.3 y	-	-	-	-	0.07	0.07
antimony-125	2.7 y	-	-	-	0.03	-	-
ruthenium-106	368 d	-	0.001	0.002	0.04	-	-
manganese-54	313 d	-	-	-	0.04	-	-
cerium-144	284 d		-	-	0.02	-	-
zirconium/niobium-95	64 d	0.08	-	-	0.2	-	-
strontium-89	52 d	-	0.001	0.03	-	-	-
ruthenium-103	39 d	0.03	-	-	0.02	-	-
cesium-136	13 d		0.002	0.002	-	-	-
barium/lanthanum-140	13 d	0.2	-	0.006	0.05	-	-
iodine-131	8 d	0.02	5 [30][a]	0.001	-	0.4 [2][a]	0.00009 [0.0002][a]
tellurium/iodine-132	3.3 d	0.1	0.06	0.001	-	-	-
neptunium-239	2.4 d	0.02	-	-	-	-	-
iodine-133	0.9 d	0.02	0.04	-	-	-	-
zirconium/niobium-97	17 h	0.02	-	-	-	-	-
rounded totals:		0.5	5 [30][a]	0.1	0.7	0.7 [2][a]	0.6 [0.9][a]

Figure 4.The map below shows estimated cesium level throughout the United States from the weapons testing at the NTS. Washington County is estimated to have received from 300-1000 bq/m2 according to this map. (taken from American Scientist Magazine)

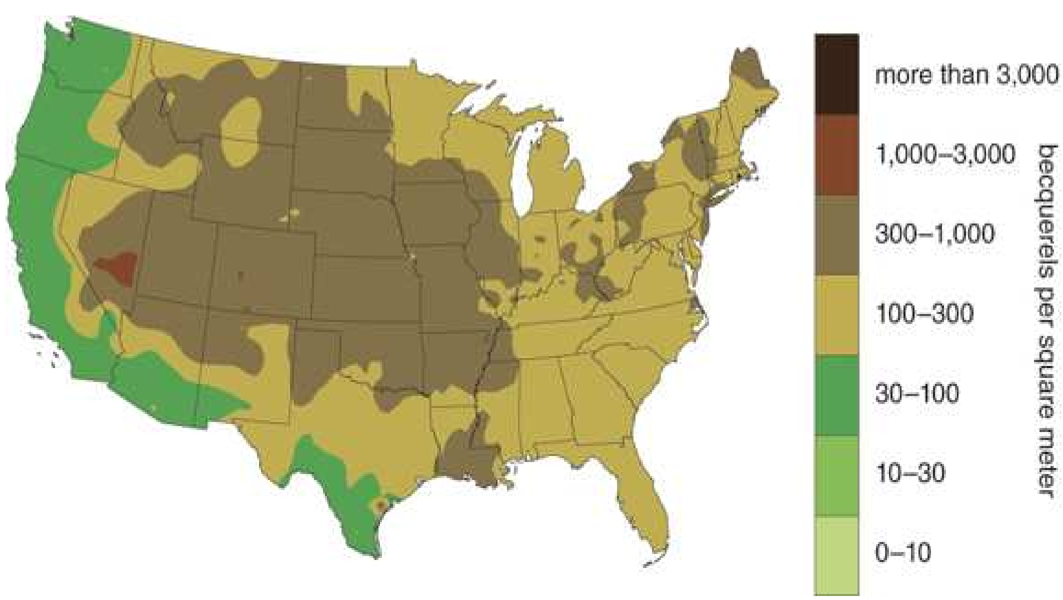
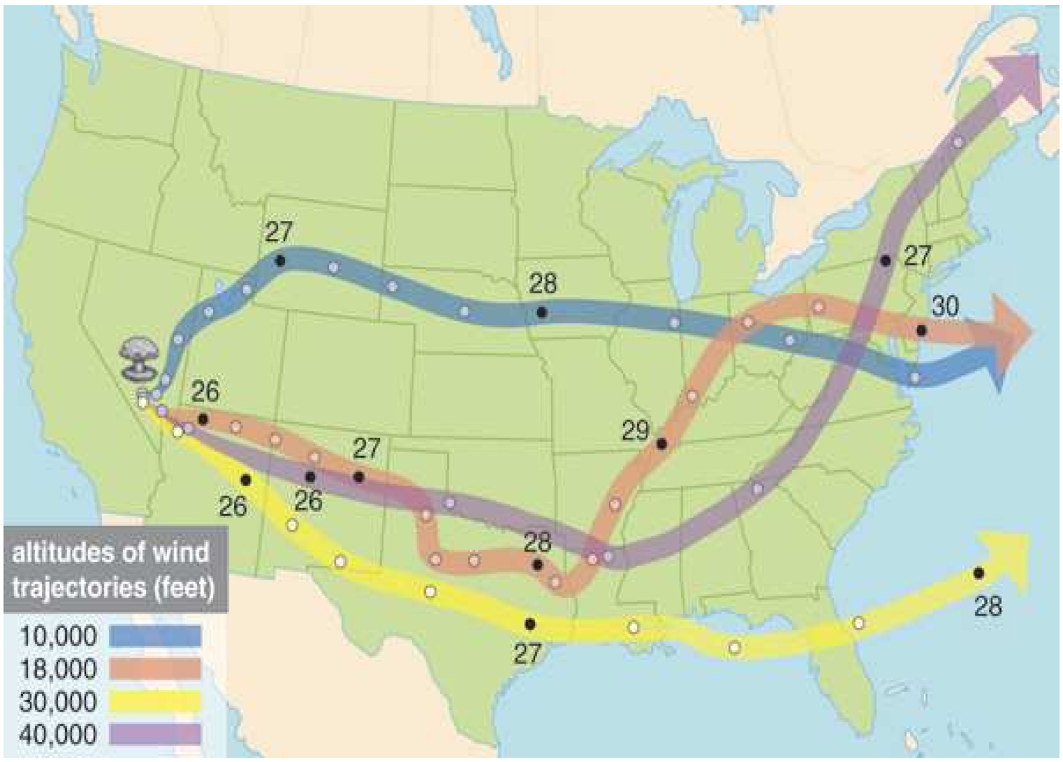


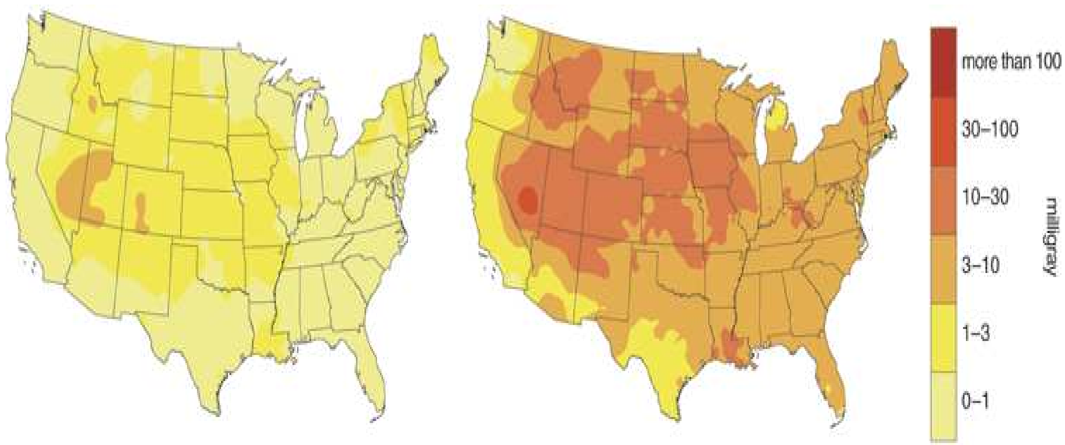
Figure 5 The map below shows an example of trajectory patterns of fallout at different altitudes from testing at the NTS. It is a good example of how fallout can spread over a very wide geographic area. This is the pattern of one specific test so the areas of spread would have been different for each explosion depending on the wind direction on the day of the test (taken from American Scientist Magazine)



David Wheeler from the US Dept of Energy in 1990 presented information to the people of Washington County showing dose estimates from the above ground testing to people in the area. (Wheeler 1990) He stated that the NTS contributed only a minimal amount of the atmospheric contamination from all above ground nuclear testing. He also assured the public that since the above ground testing ended in 1962, very little off-site contamination occurred from underground test leakage. His maps predicted the total radiation exposure level for people living in the St George area for the entire time the tests were conducted was around 3-5 rem. Kane and Iron Counties were predicted to have been exposed to1-2 rem.

The National Cancer Institute has funded studies attempting to estimate the number of cancer deaths caused by nuclear testing around the world. These studies estimated doses received by populations of people living in various areas and quantified risks associated with those doses. Iodine 131 was named as the nuclide most dangerous for causing cancer because of its tendency to easily enter milk, which children would drink and then it would collect in the child's thyroid gland. (Dept of Health 2001) Although any Iodine131 that was dispersed by above ground testing would have completely decayed by now, the Iodine 131 data can also be used to estimate the existence of cesium. These studies showed that the highest levels of Iodine occurred in the following areas. Although this study is focusing on cesium contamination, these iodine maps are helpful to show areas where the total fallout was heavily concentrated and where high doses of Cs 137 might be discovered.

Figure 6The map below estimates the total body red marrow dose received in the United States from testing at the NTS on the left, and thyroid dose to the same population on the right. (taken from American Scientist Magazine)



<u>Studies measuring contamination following the above ground testing</u>.

Several studies have been conducted in an attempt to quantify the amount of radioactivity still existing in the area as a result of the NTS nuclear weapons tests. Some notable examples of these studies are: In 1998, a study presented in the Journal Chemosphere attempted to quantify the amount of NTS contamination by sampling both attic dust and soil in several communities downwind from the testing. (Cizdziel, James V 1998) They tested for both cesium and plutonium in these regions and attempted to calculate the ratio between these two nuclides in order to prove that most of the contamination in these areas was contributed by weapons testing in Nevada. The assumption was that ratio of radiocesium/plutonium in worldwide contamination is 34. Any ratio below that level was determined to have been caused by weapons testing at the NTS.

Measurements taken from both soil and attic dust showed that all ratios in these downwind areas were lower than 34. The closer in proximity to the test range, the lower the ratio. Soil sample contamination readings generally matched the dust samples in the same region suggesting that attic dust originated from a local source, not distant fallout.

Another study by E.M. Romney et al in 1983 tested soil, plant and animal samples in specific locations to determine how much the existing radioactive contamination changed over time. Some of the locations originally used for dose measurement during the above ground testing were revisited over several years. Soil and plants were sampled. Mice and jackrabbits were trapped and killed to test muscle and bone contamination.

The overall result showed that cesium existed in samples of soil, plants, and animals in all locations of previous contamination. The cesium in the soil had only penetrated from 5-7 centimeters because of the arid climate and was easily absorbed into local vegetation and thereafter passed to the animal population. It also suggested that the level of contamination diminished in magnitude only in line with the half-life of the nuclide, and didn't diminish much because of erosion. Therefore, long-lived radionuclide contamination would most likely continue to exist almost indefinitely.

Articles written by "Downwinder" anti-nuclear groups.

The "Downwinder" community has published a great deal of information concerning the nuclear weapons testing at the Nevada Test Site and other places in the world. Their dose estimates differ greatly from those estimated by the government and most of the articles rely heavily on emotional anecdotal information from people who lived in Southern Utah at the time of the testing.

In his publication “Killing Our Own” Charles Wasserman presented the following information concerning some of the series of nuclear tests in 1956 and 1957. These stories show the emotional nature of the issue of nuclear fallout to people living in this area. (Wasserman et al 1982)

For residents downwind, radioactive fallout had indeed become a fact of life. Living in the rural rangelands north of the test site, Martin Bardoli was just beginning elementary school in 1956 when he was diagnosed with leukemia. He died before the end of the year. Believing the fallout clouds were responsible, Martin’s parents circulated a petition and sent it to their senators and the Atomic Energy Commission. In his responding letter, Senator George Malone warned against alarmism about fallout. And the senator added. “it is not impossible to suppose some of the scare stories are Communist inspired.”

Stationed in Southern Nevada, Marine Major Charles Broudy placed a long distance call to his wife on July 4th 1957. Excitement and urgency were in his voice when he told his wife “You’ve got to get the kids up and face the east tomorrow about 4:00 Nevada time. You’ll see a miracle.” The miracle was a massive atomic explosion named Hood that official logs peg at 74 kilotons. Charles Broudy later died of lymphoma and after research with the help of Princeton University physicist Frank Von Hippel, his wife found that the Hood shot had exposed her late husband to about 70 thousand millirads of radiation- about 5000 times above the thirteen millirad the government said his film badge read at the test blast.

Figure7. Below is a picture taken of a blast that was part of a test to determine how troops would react in a combat situation following a nuclear explosion. Troops were commanded to watch the explosion, and then were marched into the ground zero area soon afterwards. .(U.S.DOE/NNSA 2007)

In a lecture to the Hunter College Energy Studies program in 1986, Lorna Salzman stated the following concerning the cover-up of nuclear exposures from the above ground testing: “The Nevada test site fallout didn’t stay put, however. It drifted downwind into Mormon areas in Utah. Several years later, leukemia, lymphomas and other cancers and genetic effects began emerging in this area, particularly among children. The AEC continually stated to the local residents that “there is no danger” and most studies done about this area and about nuclear tests in general were secret until 1979. An AEC booklet distributed 6 years after the testing said” Nevada test fallout has not caused illness or injured the health of anyone living near the test site.”(Salzman1986)

Stories like this are commonplace in this group of people and throughout small towns in the vicinity of the testing. There is a strong underlying mistrust of the government concerning the testing and doses received that is still evident today among people who were alive at the time of the testing.

Methods and Materials

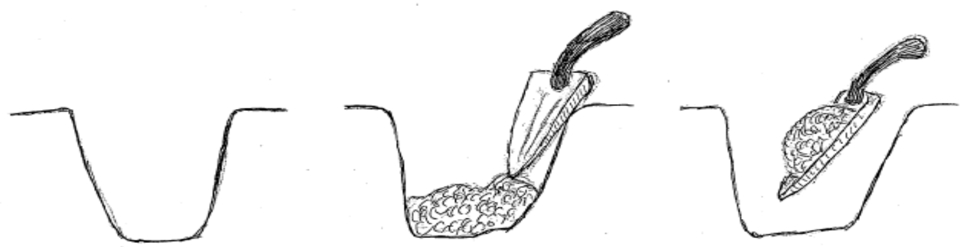
Soil sampling and testing for this study were performed using the following methods:

1. Selections of location for soil samples- Soil samples were collected from various locations throughout Southwest Utah. Washington County was identified as having one of the highest cesium levels in the country after the above ground nuclear testing was completed. (see figure 2 on page 19) Therefore, most of the samples were collected in that county. Other samples were also taken from locations in Iron County to the North, Kane County to the East, and Coconino County in Northern Arizona to the South.

Washington County is also one of the fastest growing counties in the United States. Several regions of the county that were considered uninhabited years ago, are now locations for new housing developments. Many of the soil samples were taken in undisturbed soil at the edge of these new housing developments in order to make sure that high levels of cesium do not exist there. The total number of samples collected was 102. 85 of the samples were taken from Washington County, 5 from Kane County, 8 from Iron County, and 4 from Coconino County in Arizona.

2. Methods used in collecting soil samples- It was difficult to determine what the best depth would be to use for soil sampling. A study by Romney et al showed that in this arid environment, contamination often doesn't penetrate more than a few centimeters even after many years. (Romney, E.M. et al 1983) However, some of the soil in this area is sandy and water is easily absorbed in it. Other parts of the area have high concentrations of clay and others are very rocky. The absorption of contamination in each of these types of soil would obviously be different. It was therefore determined that the best method would be to test the soil at varying depths. This was accomplished in the following manner: First a hole was dug into the soil using a small hand spade to a depth of approximately 6 to 8 inches. All of the soil was then taken from inside the hole. The soil on the inside edges was then scraped into the bottom of the hole, being careful to dislodge dirt for the entire hole depth. This dirt was then removed from the hole and placed in the container being careful to include soil from all depths. (See diagrams) After a sample of soil including all different soil depths within the hole was achieved, the hole was then filled back in with the remaining dirt. Soil was stored in cottage cheese size 16 oz containers and labeled with numbers that were used to keep track of the location of the soil samples.

Figure 8. The diagrams below illustrate the method used to collect soil samples for this study.



Packaging and shipping of samples to Oregon State University for testing.

After the soil was collected, the number of the container was recorded with the physical location of each sample listed next to the number. These locations were then given GPS coordinates using the Google Earth Internet program to increase the accuracy and reproducibility of the sample site. The containers were individually taped shut with packing tape to insure they would be safe during shipping. They were boxed up in groups of 25, and sent to the Oregon State University Radiation Center for testing.

Sample testing methodology. Soil testing was accomplished at Oregon State University using an HP Germanium detector. Samples were left in the cottage cheese type containers they were packaged in for shipment and were placed on top of the detector. The detector is located in a small area completely encased in lead bricks, including a lead-brick top that is pulled over the detector after the sample is placed upon it. These detectors are so radiosensitive that room light causes measurable ionization in them so this shielding is necessary to make sure no background radiation is detected. Each sample was left on the detector for 80,000 seconds or a little more than 22 hours.

Doses were calculated using the Ortec Gammavision-32 Software Program version 6. These results were sent from the OSU Radiation Center to St George Utah, initially via email file, and at the conclusion of all testing on a CD. A copy of the actual Ortec reports will be attached in a digital file and sent with this thesis as Appendix 1

Results:

Table 4. There were 102 soil samples tested for this study. The location of the samples and their detected cesium 137 levels are listed below. The readings have been converted to Bq/m2.

Number	Location	Bq/m2
1.	Canyon Terrace west facing hillside	184.7
2.	Canyon Terrace east facing hillside	165.0
3.	Lava Cove near biking trail	892.4
4.	Pioneer Parkway trail near tunnel	68.1
5.	Riverbed below Santa Clara Heights	000
6.	Desert across from Lava Ridge School	113.9
7.	Ivins town, 400 East near Red Mountain	35.1
8.	Hillside above Ivins Cemetary	132.4
9.	Hillside above Kayenta water tank	471.0
10.	Desert Reserve trailhead near Tuacahn	919.4
11.	Wash below Scout Cave near Ivins	39.7
12.	Castlerock Trail head	49.3
13.	Westside of Foremaster Ridge	192.6
14	Eastside of Foremaster Ridge	193.4
15.	Apple Valley near Hayden Residence	171.6
16.	Purgatory Flat near Quail Lake	29.4
17.	Above Hurricane Hill near Ostrich Farm	98.1
18.	Flora Tech road near Brentwood	196.1
19.	Base of Hurricane Hill	889.9
20.	Colorado City outskirts	63.4
21.	Mt Carmel gravel pit	81.9
22.	Mt Carmel lane near feedlot	40.2
23.	Plateau on Sugar Knoll trail	202.8
24.	Cane Beds wash	786.6

25.	Hillside above Orderville Cemetery	43.1
26.	Slide area below Buffalo ranch	35.6
27.	Desert below Smith's Mesa	87.1
28.	Santa Clara near Country Lane	211.4
29.	River bottoms near Sunbrook Golf Course	207.5
30.	Hillside above Sunbrook Golf Course	899.0
31.	Hillside above Moore Business Forms	163.0
32.	Across from Tonaquint Nursery	188.2
33.	Little League Hill trail	346.7
34.	Indian Hills above Maverick Station	273.2
35.	Black Hill west of airport	461.3
36.	Black Hill above Shadow Mountain	323.0
37.	Tonaquint Terrace behind Bloomington	100.2
38.	West Bloomington bike path	1082.5
39.	Pioneer Road Bloomington near Calvary Church	271.7
40.	Sun River Wash	850.8
41.	Brigham Road across from gravel pit	625.6
42.	Hillside behind Desert Hills School	642.2
43.	Desert in front of Armory	38.4
44.	Ledges behind Armory	241.0
45.	Little Valley Overlook	408.7
46.	Old air strip	469.4
47.	Little Valley Intermediate School	587.7
48.	The Boulders subdivision	890.2
49.	Dr's Free Clinic trail	115.4
50.	Convention Center Trailhead	563.8
51.	Black Ridge below airport	945.0
52	Black Ridge Middle of D	522.6
53.	Black Hill near Phoenix Plaza	427.2
54.	Seven Hills subdivision	246.2
55.	Santa Clara behind Dutchman's Market	30.2
56.	Hillside behind Santa Clara Valley Church	41.8
57.	Jacob Hamblin Home trail	121.7
58.	Santa Clara River below Post Office	258.8
59.	River bottoms below Ivins turn off	273.9
60.	End of Riverwood lane Santa Clara	93.5
61.	Desert across from Costco	942.8
62.	Sand Hollow subdivision	381.0
63.	Sand Hollow campground	411.8
64.	Copperleaf subdivision near exit 13	62.2
65.	Bella Vista subdivision entrance	714.3
66.	Across from Valley View M.C.	323.7
67.	Red Hills Parowan	322.3
68.	Near Broad Canyon Parowan	1171.1

69.	"P" Hill Parowan	185.6
70.	Parowan Dump	780.0
71.	Summit Canyon	228.4
72.	Webster Hill near Enoch	969.8
73.	Kanarraville foothills near exit	394.0
74.	New Harmony near first bus stop	435.2
75.	Pintura	151.7
76.	Silver Reef	290.4
77.	Leeds- Hidden Valley	1026.1
78.	Coral Canyon North	440.0
79.	Green Springs	101.3
80.	Turtle Road trailhead	444.5
81.	The Ledges subdivision	182.9
82.	Winchester Hills	171.6
83.	Diamond Valley	360.1
84.	Dammeron Valley	201.4
85.	Veyo Pool road	413.1
86.	Brookside	269.1
87.	Hillside above Pine Valley Church	491.6
88.	Behind Pine Valley Cemetery	733.8
89.	Central	459.1
90.	Mountain Meadow	1821.6
91.	Enterprise Rock Quarry	859.5
92.	Hillside above Enterprise High School	1256.1
93.	Highway 120 West of Enterprise	945.8
94.	Terry Ranch Road	1245.1
95.	Anasazi Valley	208.7
96.	Arizona Strip Utah Border	204.8
97.	Arizona Strip 5 miles south of border	32.2
98.	Shivwits Reservation near Santa Clara River	464.3
99.	Wash below Gunlock Reservoir	237.1
100.	Hillside above Gunlock Reservoir	700.4
101.	Gunlock Rodeo Grounds	33.7
102.	Plateau above Gunlock	347.8

A map showing the geographic location of these sites is presented below on page 40

A chart showing the actual GPS coordinates of these samples is located in Appendix 2

Discussion

Testing of the soil samples yielded several important items of interest.

1. Cesium still exists throughout all areas of Southwestern Utah. Over 99 percent of soil samples tested contained detectable levels of cesium. This was true of Washington, Iron, and Kane Counties in Utah, and also Coconino County in Arizona. Cesium levels seemed slightly lower in Kane County, but the other areas were very similar in contamination amounts.

Table 5. A summary of samples taken and the average cesium level detected is as follows. Readings in Bq/m2

A. Washington County-	84 soil samples tested. Average reading- 380.7
B. Kane County-	5 soil samples tested. Average reading- 80.7
C. Iron County-	8 soil samples tested. Average reading- 534.5
D. Coconino County	4 soil samples tested. Average reading- 271.8

2. Radiation contamination is lower in sandy soil. Of the samples tested in soil composed mostly of sand, the average contamination reading was 75.92 Bq/m2. When the sandy soil measurements were subtracted from the other soil samples, soil without sand in Washington County had an average contamination level of 421.9 Bq/m2. Most of the areas of sandy soil were near streambeds or parts of sand dune areas. It is assumed that this type of soil would very easily absorb contamination, and any contamination would probably be either deeper in the soil or eroded away in these more sandy areas.

3. Cesium levels in Southern Utah may be higher than previous estimates have shown. Most of the studies that estimated cesium contamination used bq/m2 as

the reference contamination density level. In order to convert my soil sample size to fit that reference size, these calculations were used:

Given-

The holes dug to obtain the soil samples for testing were generally no more than 10cm across.

A ten cm hole covers an area of 100 cm2

One m2 area converts to 10,000 cm2 or about 100 times the size of a 10 cm hole.

The half life for cesium 137 is 30 years, therefore, it has been approximately 2 half lives since the Nuclear Weapons testing occurred at the NTS.

The amount of contamination remaining in the soil from the testing will therefore be about ¼ of the original deposition density that was deposited during the weapons testing without taking into account absorption into the soil.

Combine that with the difference in size of the sample, (a factor of 100) and a rough calculation could be run in order to estimate how much contamination existed immediately after the testing and compare that to the estimates which were presented earlier

Simply take the contamination density we measured in our cottage cheese container 600ml samples and multiply them by 400 in order to get a rough estimate of the number of bq of cesium that existed per m2 immediately after the testing was completed (assuming no erosion or deep soil absorption.)

The previously cited studies by the Department of Health and Human Services estimated the cesium density deposited in this area by the nuclear testing in Nevada to be in a range of 800 - 1300 bq/m2 in Washington County, 600-800 in Iron County, 600-800 in Kane County and 200-400 in Coconino County. Another map presented earlier estimated contamination density to be even lower than that.

The soil samples collected and tested for this study would suggest that the levels were more in the range of 1000-5000 in Washington County, 1000-3000 in Iron County, 200-400 in Kane County, and 300-2000 in Coconino County.

4. The type of topography and soil also makes a difference in the contamination levels. It was mentioned earlier that sandy soil contributed to many of the lower readings in the soil samples. On the other end of the spectrum, 24 of the soil samples tested had density levels of 600 bq/m2 or higher. Most of these higher readings had 2 things in common. First, they were located on hillsides, not in valleys. It would seem that particles suspended in the air were deposited more readily in these areas because of the turbulence created when the wind moved around the hillsides. Second, the soil was mostly made up of white shale and limestone instead of the red sand that was present in the lower readings. The contamination evidently stayed closer to the surface in this type of soil because the particle size of the soil is much smaller and doesn’t absorb as readily.

5.Some regions have considerable differences in contamination levels. For reference, the Southwest part of the state has been divided into 13 different geographical areas.

The highest, the lowest and the average reading within each of these areas is listed in order to present the data in a more organized fashion.

Table 6. Cesium Contamination Readings for Several Geographic Areas in the Southern Utah Area

Area	Maximum	Minimum	Average
St George West	945.0	163.0	498.4
Ivins West	919.4	33.7	326.3
St George South	1082.4	38.4	419.4
St George East	942.8	62.2	511.9
St George North	892.4	0	239.1
Hurricane/Leeds	1026.1	29.4	347.8
Northern Arizona	786.6	32.3	271.8
Kane County	202.8	35.6	80.7
Iron County	1171.1	185.6	534.5
Highway 18	733.8	172.6	364.9
Enterprise	1821.6	859.5	1225.8
Santa Clara	273.9	30.2	150.3

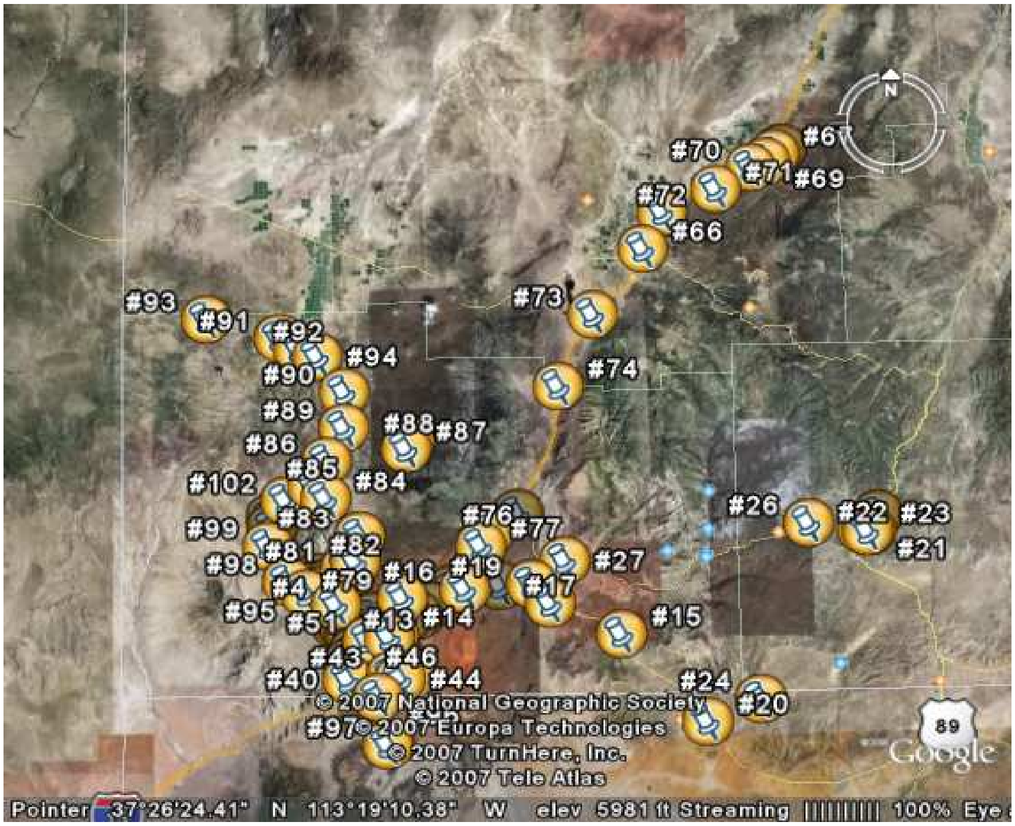
Table 6 above shows the contamination levels of different geographic areas in Southern Utah. Many of these regions areas were fairly consistent in radioactivity readings. Most were within a 100 Becquerel of each other and varied enough within a close geographical area to assume one area didn't receive a substantially higher dose than another area. Some noticeable exceptions were:

There was one geographic area within Washington County, which received a significantly higher reading than any other. This was the area surrounding the town on Enterprise, a small farming community 40 miles northwest of St George. The three highest readings recorded in the entire region were in that area, and the lowest reading in Enterprise was higher than most other area's highest readings. This difference was dramatic enough to lead me to believe that this area received a substantially higher level of contamination than the St George area. They were possibly exposed to as much as two or three times the amount of radioactivity received in other areas.

The contamination levels in Iron County were also somewhat surprising. According to the estimate maps, this area received lower cesium levels than Washington County. However, the results of the soil tests showed that Iron County's levels were as high, if not higher than those in most of Washington County. It was interesting to note that if you look at the position of the Enterprise region on a map, and compare it to Iron County; you can see that a dose cloud passing from the NTS through Enterprise would also pass across most of Iron County. The higher readings from these two locations are possibly related to the same event(s).

The Santa Clara area was also somewhat surprising because of the lower contamination levels that were measured there. There were an adequate number of samples (10) collected over a fairly wide geographic area, surrounded on all sides by regions with higher average soil readings. Santa Clara is an area however, which is protected from the wind somewhat by high bluffs, and has enough sandy soil and uneven ground to wash contamination away. The other low contamination readings from the study came from North St George which is very sandy, Northern Arizona, where I only collected 4 samples so one sample with a very small amount of contamination knocked the average down lower than I believe it would have been if I had a larger sample size, and Kane County which is 70 miles East of St George and over a long range of mountains. The Kane County samples taken in the lower valley were near nothing, but the one sample I took at a higher altitude did show a reading of more than 200 bq/m2, suggesting that there is some contamination there, just more dispersed and located in areas where high winds would have carried it

Figure 8.The map below is a Google Earth map showing all of the soil sample sites noted by the yellow tags. State and county lines as well as major roadways are also shown. (courtesy of Google Earth)



<u>6.The radiation exposure from this cesium contamination is relatively low</u>.

One of the main concerns with establishing the existence of radioactive contamination in any area is whether or not the exposure from that contamination creates a health hazard for people living in the area. It was mentioned earlier that many of the soil samples were taken near new subdivisions and several were even collected near schools to make sure some of these previously remote areas are now safe to inhabit.

The EPA has established a dose formula for estimating radiation exposure to humans from ingestion of different radionuclides. (US EPA 1993) The entire nuclide exposure chart is located in Appendix 3.

Using the highest dose level of any sample taken which was 1826 Bq/m2 at an area near Enterprise Utah, and applying it to the EPA formula, we receive the following results: The formula takes into account radioactive decay and gives an estimate for the first month of exposure, the second month of exposure and a lifetime or 50 year exposure estimate. The first month exposure estimate for this sample location is .178 mrem, the second month estimate is .169 mrem, and the 50-year estimate from living in an area with this level of contamination is 23.4 mrem. These levels are relatively low in comparison to levels allowed by radiation workers. A radiation worker is allowed to receive an external exposure of up to 5000 mrem /year as part of their occupation and is not even required to be notified until that level reaches 500 mrem/year. However, the EPA has set contamination limits on soil and water that are meant to limit the public to no more than 4 millirem internal dose annually from ingesting any photon or beta producing nuclide. (ToxFAQ 2004) The annual dose estimate from our calculation, if carried out for an entire year would yield a dose of approximately 1.5 mrem. This is well within the EPA guidelines, but also shows that in the past, prior to nuclear decay and erosion, some areas may have been contaminated with levels of cesium higher than current EPA standards.

Conclusion

Almost sixty years have passed since nuclear weapons testing began at the Nevada Test Site. More than one hundred above ground tests and many more below ground tests initially exposed the public to varying levels of radioactivity and have since left a legacy of contamination in areas downwind from the NTS.

Although most of the fission products from the weapons testing have decayed away, several of the longer-lived nuclides still exist in measurable levels.

This study tested over one hundred soil samples in the Southwest Utah area to determine the existing level of one of the remaining products of nuclear weapons testing- cesium137. 101 out of 102 samples tested showed measurable levels of this nuclide.

Areas North of St George such as Enterprise and Iron County had the highest levels of cesium. Santa Clara and Kane County both had lower levels of cesium, but no region was found to be without at least some contamination.

Soil samples with high sand content generally contained lower readings than those with high clay or limestone components. Hillsides averaged higher readings than valleys and East and West facing hillsides showed nearly identical readings on both sides of the hill.

Overall, the readings averaged higher than would have been expected from earlier estimates. The average contamination reading for all of Washington County was 380.7 Bq/m2. The amount we assumed to be here from the estimates we found was around 275 Bq/m2.

The reasons for this 38% difference in contamination levels are not fully understood. Perhaps the estimates are simply wrong and this area received a higher level of contamination than was originally calculated. Or maybe some of the measured dose is a result of additional cesium contamination from worldwide fallout. Those are questions to be answered another day with additional information.

The contamination levels found in this region are widespread, but still however, relatively low in magnitude, and present a very minimal risk to people living in the area at the present time.

Nuclear weapons testing at the Nevada Test Site left a legacy of radioactive contamination for the current generation and many to come. My only hope is that we have learned our lesson and do nothing in the future to add to the contamination that remains.

APPENDICES

Appendix 1
A digital copy of the actual Ortec Gammavision 32 soil sample result reports showing all nuclides found in the soil is attached as a word file in the same e-mail with this final thesis draft.

Appendix 2
Below are the GPS readings and results of the soil samples in the study. The location measurements were taken using the Google Earth internet program.

Number	Location	Bq/container
1.	37 08’11.26” N 113 38 ‘17.65 “ W	1.69
2.	37 08’16.08” N 113 38 ‘ 15.50 “ W	1.65
3.	37 08’18.93” N 113 38 ‘ 26.33 “ W	8.92
4.	37 08’39.93” N 113 38 ‘ 59.39 “ W	.681
5.	37 08’36.21” N 113 39 ‘ 07.87 “ W	000
6.	37 09’04.25” N 113 39 ‘ 38.35 “ W	1.14
7.	37 10’08.54” N 113 40 ‘ 08.08 “ W	.351
8.	37 10’37.55” N 113 40 ‘ 59.57 “ W	1.32
9.	37 10’59.07” N 113 41 ‘ 02.44 “ W	4.71
10.	37 10’39.66” N 113 39 ‘ 01.66 “ W	9.19
11.	37 10’05.82” N 113 37 ‘ 51.30 “ W	.347
12.	37 08’40.00” N 113 37 ‘ 09.56 “ W	.493
13.	37 05’35.22” N 113 33 ‘ 01.53 “ W	1.93
14	37 05’49.57” N 113 32 ‘ 35.66 “ W	1.93
15.	37 06’01.81” N 113 07 ‘ 53.51 “ W	1.72
16.	37 09’57.64” N 113 24 ‘ 15.13 “ W	.294
17.	37 07’24.89” N 113 11 ‘ 43.91 “ W	.981
18.	37 09’57.45” N 113 22 ‘ 06.49 “ W	1.96
19.	37 10’31.78” N 113 17 ‘ 62.53 “ W	8.90
20.	36.57’15.94” N 112 57 ‘ 50.79 “ W	.633
21.	37 14’45.43” N 112 39 ‘ 15.53 “ W	.819
22.	37 14’54.60” N 112 39 ‘ 57.27 “ W	.402
23.	37 14’32.15” N 112 39 ‘ 15.47 “ W	2.03
24.	37 01’08.38” N 112 49 ‘ 45.42 “ W	7.87
25.	37 16’21.08” N 112 38 ‘ 10.29 “ W	.431
26.	37 15’34.22” N 112 45 ‘ 57.67 “ W	.356
27.	37 12’29.28” N 113 13 ‘ 26.99 “ W	.871
28.	37 07’11.43” N 113 38 ‘ 20.15 “ W	2.11
29.	37 06’43.01” N 113 38 ‘ 04.15 “ W	2.09
30.	37 06’37.68” N 113 38 ‘ 46.99 “ W	8.99
31.	37 06’01.78” N 113 37 ‘ 21.99 “ W	1.63
32.	37 05’06.77” N 113 36 ‘ 30.31 “ W	1.88

33.	37 07’56.27” N 113 38 ‘ 17.81 “ W	3.47
34.	37 04’40.26” N 113 35 ‘ 28.43 “ W	2.73
35.	37 05’28.55” N 113 36 ‘ 15.16 “ W	4.61
36.	37 06’21.11” N 113 36 ‘ 19.17 “ W	3.23
37.	37 04’02.48” N 113 36 ‘ 54.06 “ W	1.00
38.	37 03’12.59” N 113 37 ‘ 29.18 “ W	1.08
39.	37 02’19.90” N 113 36 ‘ 03.05 “ W	2.72
40.	37 01’58.19” N 113 37 ‘ 45.65 “ W	8.51
41.	37 03’21.75” N 113 34 ‘ 35.68 “ W	6.26
42.	37 02’55.37” N 113 33 ‘ 48.04 “ W	6.42
43.	37 02’04.67” N 113 32 ‘ 48.38 “ W	.384
44.	37 02’02.44” N 113 31 ‘ 58.30 “ W	2.41
45.	37 02’40.39” N 113 31 ‘ 04.36 “ W	4.09
46.	37 02’00.01” N 113 29 ‘ 52.29 “ W	4.69
47.	37 03’35.49” N 113 31 ‘ 50.28 “ W	5.88
48.	37 04’51.11” N 113 32 ‘ 50.70 “ W	8.90
49.	37 05’11.18” N 113 33 ‘ 46.02 “ W	1.15
50.	37 04’23.66” N 113 35 ‘ 01.80 “ W	5.64
51.	37 05’20.16” N 113 35 ‘ 22.79 “ W	9.45
52	37 06’29.51” N 113 35 ‘ 53.49 “ W	5.23
53.	37 07’25.08” N 113 36 ‘ 05.97 “ W	4.27
54.	37 07’45.68” N 113 37 ‘ 57.51 “ W	2.46
55.	37 07’42.08” N 113 38 ‘ 22.36 “ W	.302
56.	37 08’07.99” N 113 39 ‘ 17.86 “ W	.418
57.	37 08’02.55” N 113 39 ‘ 46.38 “ W	1.22
58.	37 07’33.74” N 113 38 ‘ 57.28 “ W	2.59
59.	37 08’39.89” N 113 40 ‘ 34.15 “ W	2.74
60.	37 07’27.90” N 113 38 ‘ 46.06 “ W	.935
61.	37 07’22.31” N 113 31‘ 08.83 “ W	9.43
62.	37 07’57.28” N 113 22 ‘ 58.97 “ W	3.81
63.	37 07’41.84” N 113 22 ‘ 43.66 “ W	4.81
64.	37 08’19.81” N 113 28 ‘ 41.74 “ W	.623
65.	37 07’54.73” N 113 28 ‘ 42.76 “ W	7.14
66.	37 41’59.93” N 113 03 ‘ 43.90 “ W.	3.24
67.	37 50’54.56” N 112 48 ‘ 18.22 “ W	3.22
68.	37 51’34.67” N 112 47 ‘ 21.23 “ W	11.71
69.	37 50’08.10” N 112 49 ‘ 30.43 “ W	1.86
70.	37 49’34.76” N 112 51 ‘ 06.27 “ W	7.80
71.	37 47’37.32” N 112 55 ‘ 14.71 “ W	2.28
72.	37 45’26.15” N 113 01 ‘ 25.35 “ W	9.70
73.	37 35’44.28” N 113 09 ‘ 33.84 “ W	3.94
74.	37 28’58.31” N 113 13 ‘ 44.67 “ W	4.35
75.	37 19’33.41” N 113 17 ‘ 11.89 “ W	1.52
76.	37 15’66.30” N 113 21 ‘ 43.77 “ W	2.90
77.	37 14’11.57” N 113 22 ‘ 38.69 “ W	10.26

78.	37 10’05.22” N 113 25 ‘ 55.37 “ W	4.40
79.	37 09’17.62” N 113 31 ‘ 32.08 “ W	1.01
80.	37 07’32.97” N 113 34 ‘ 52.87 “ W	4.45
81.	37 11’35.37” N 113 37 ‘ 56.56 “ W	1.83
82.	37 12’39.38” N 113 37 ‘ 02.50 “ W	1.73
83.	37 14’58.66” N 113 36 ‘ 00.16 “ W	3.60
84.	37 18’57.02” N 113 40 ‘ 00.57 “ W	2.02
85.	37 19’54.49” N 113 41 ‘ 28.20 “ W	4.13
86.	37 22’09.40” N 113 40 ‘ 00.28 “ W	2.69
87.	37 23’18.12” N 113 30 ‘ 57.84 “ W	4.92
88.	37 24’00.23” N 113 30 ‘ 31.93 “ W	7.34
89.	37 25’20.64” N 113 37 ‘ 54.76 “ W	4.59
90.	37 28’40.05” N 113 37 ‘ 53.78 “ W	18.22
91.	37 33’53.42” N 113 45 ‘ 11.50 “ W	8.59
92.	37 32’53.46” N 113 43 ‘ 01.70 “ W	12.56
93.	37 35’57.93” N 113 53 ‘ 59.57 “ W	9.46
94.	37 32’00.59” N 113 40 ’ 51.76 “ W	12.45
95.	37 10’08.67” N 113 43 ‘ 08.82 “ W	2.09
96.	36 59’33.46” N 113 34 ‘ 18.93 “ W	2.05
97.	36 55’35.21” N 113 33 ‘ 19.55 “ W	.322
98.	37 10’38.44” N 113 45 ‘ 01.81 “ W	4.64
99.	37 14’42.59” N 113 46 ‘ 30.98 “ W	2.37
100.	37 15’58.26” N 113 46 ‘ 04.05 “ W	7.00
101.	37 16’58.34” N 113 46 ‘ 09.24 “ W	.337
102.	37 18’33.93” N 113 44 ‘ 25.15 “ W	3.48

Appendix 3
The following is section from an article showing the exposure calculation estimates for radionuclides in the soil. It is taken from a 1993 EPA report.

Calculation of effective dose from exposure to ground contamination.

1) Equation

The effective dose calculated includes the external dose and committed dose from inhalation (resuspension) resulting from remaining on contaminated ground for the period of concern – first month, second month or lifetime (50 years). Once the radionuclide concentrations on the ground are known, the effective dose can be estimated. The equation is:

$$E_t = C_{ground} \ x \ CF_{ground,t}$$

Where

E_t = Effective dose [mSv] from deposition over the time interval t, where t = first month, second month or 50 years.

C_{ground} = Average ground concentration of radionuclide [kBq/m^2].

$CF_{ground,\,t}$ = Conversion factor: effective dose per unit deposition for radionuclide for the specified time interval t = first month, second month or 50 years (mSv/kBq/m^2). Includes external dose and committed effective dose from inhalation due to resuspension resulting from remaining on contaminated ground for the period of concern.

The equation should be calculated for each radionuclide present and the effective doses should be summed.

2) Conversion factors

Radionuclide	**Conversion factor (mSv/kBq/m^2)**		
	1st month	**2nd month**	**50 years**
C-14	5.2E-07	4.9E-07	1.0E-04
Na-22	3.7E-03	3.4E-03	8.4E-02
Na-24	2.0E-04	0.0E+00	2.0E-04
P-32	5.3E-06	1.2E-06	6.8E-06
P-33	1.1E-06	4.4E-07	1.8E-06
S-35	1.2E-06	8.7E-07	4.7E-06
Cl-36	8.1E-06	7.7E-06	1.6E-03
K-40	2.6E-04	2.5E-04	5.3E-02
K-42	1.2E-05	0.0E+00	1.2E-05
Ca-45	2.9E-06	2.4E-06	1.8E-05
Sc-46	3.0E-03	2.2E-03	1.2E-02
Ti-44+Sc-44	4.0E-03	3.8E-03	5.9E-01
V-48	2.8E-03	7.1E-04	3.7E-03
Cr-51	3.8E-05	1.7E-05	6.9E-05
Mn-54	1.4E-03	1.2E-03	1.4E-02
Mn-56	1.5E-05	0.0E+00	1.5E-05
Fe-55	9.1E-07	8.5E-07	2.2E-05
Co-58	1.6E-03	9.4E-04	3.9E-03
Co-60	4.2E-03	3.9E-03	1.7E-01
Ni-63	5.3E-07	5.0E-07	9.1E-05

Radionuclide	Conversion factor (mSv/kBq/m²)		
	1st month	2nd month	50 years
Cu-64	8.6E-06	0.0E+00	8.6E-06
Zn-65	9.4E-04	8.2E-04	8.0E-03
Ge-68+Ga-68	1.6E-03	1.4E-03	1.5E-02
Se-75	6.2E-04	4.9E-04	3.1E-03
Rb-86	1.0E-04	3.2E-05	1.5E-04
Sr-89	1.1E-05	6.6E-06	2.8E-05
Sr-90	1.7E-04	1.6E-04	2.1E-02
Sr-91	3.4E-05	7.5E-08	3.4E-05
Y-90	1.7E-06	6.7E-10	1.7E-06
Y-91	1.7E-05	1.1E-05	4.9E-05
Y-91m	1.6E-06	6.5E-09	1.6E-06
Zr-93	2.2E-05	2.1E-05	4.8E-03
Zr-95	1.4E-03	1.3E-03	6.8E-03
Nb-94	2.7E-03	2.6E-03	5.5E-01
Nb-95	1.0E-03	5.2E-04	2.1E-03
Mo-99+Tc-99m	6.1E-05	3.1E-08	6.1E-05
Tc-99	4.1E-06	3.9E-06	8.2E-04
Tc-99m	2.7E-06	1.2E-14	2.7E-06
Ru-103	6.4E-04	3.6E-04	1.5E-03
Ru-105	1.4E-05	1.8E-12	1.4E-05
Ru-106+Rh-106	4.2E-04	3.8E-04	4.8E-03
Ag-110m	4.5E-03	3.9E-03	3.9E-02
Cd-109+Ag-109m	6.4E-05	5.8E-05	8.6E-04
Cd-113m	1.1E-04	1.1E-04	9.2E-03
In-114m	4.5E-04	3.5E-04	2.2E-03
Sn-113+In-113m	2.2E-05	1.7E-05	1.2E-04
Sn-123	3.2E-03	3.2E-03	7.0E-01
Sn-126+Sb-126m	2.6E-03	1.7E-03	7.8E-03
Sb-124	2.4E-03	4.2E-04	2.9E-03
Sb-126m	2.3E-04	1.1E-06	2.3E-04
Sb-127	2.3E-05	4.9E-08	2.3E-05
Sb-129	3.7E-06	3.6E-08	3.7E-06
Te-127	1.8E-07	0.0E+00	1.8E-07
Te-127m	3.4E-05	2.7E-05	1.6E-04
Te-129	2.5E-07	9.7E-16	2.5E-07
Te-129m	1.1E-04	5.4E-05	2.2E-04
Te-131	1.2E-06	3.8E-08	1.2E-06
Te-131m	2.0E-04	3.3E-06	2.0E-04
Te-132	6.9E-04	1.1E-06	6.9E-04

Radionuclide	Conversion factor (mSv/kBq/m^2)		
	1st month	2nd month	50 years
I-125	7.8E-05	5.2E-05	2.4E-04
I-129	1.7E-04	1.6E-04	3.4E-02
I-131	2.5E-04	1.8E-05	2.7E-04
I-132	1.9E-05	0.0E+00	1.9E-05
I-133	4.5E-05	0.0E+00	4.5E-05
I-134	8.1E-06	0.0E+00	8.1E-06
I-135+Xe-135m	3.7E-05	0.0E+00	3.7E-05
Cs-134	2.7E-03	2.5E-03	5.1E-03
Cs-135	7.0E-07	3.9E-07	8.5E-06
Cs-136	1.9E-03	3.6E-04	2.3E-03
Cs-137+Ba-137m	9.9E-04	9.4E-04	1.3E-01
Ba-133	7.0E-04	6.6E-04	4.8E-02
Ba-140	2.0E-03	4.4E-03	2.5E-03
La-140	3.2E-04	1.2E-09	3.2E-04
Ce-141	9.9E-05	4.9E-05	2.0E-04
Ce-144+Pr-144	1.5E-04	1.3E-04	1.4E-03
Pr-144	4.0E-08	0.0E+00	4.0E-08
Pr-144m	2.2E-08	0.0E+00	2.2E-08
Pm-145	6.0E-05	5.7E-05	5.8E-03
Pm-147	4.4E-06	4.1E-06	1.0E-04
Sm-151	3.5E-06	3.3E-06	5.9E-04
Eu-152	2.0E-03	1.9E-03	1.6E-01
Eu-154	2.1E-03	2.0E-03	1.3E-01
Eu-155	1.1E-04	1.0E-04	4.2E-03
Gd-153	1.8E-04	1.6E-04	1.5E-03
Tb-160	1.7E-03	1.2E-03	5.8E-03
Ho-166m	3.1E-03	2.9E-03	6.1E-01
Tm-170	1.6E-05	1.3E-05	8.5E-05
Yb-169	4.0E-04	2.0E-04	7.9E-04
Hf-181	7.7E-04	4.5E-04	1.8E-03
Ta-182	2.0E-03	1.6E-03	9.7E-03
W-187	4.1E-05	0.0E+00	4.1E-05
Ir-192	1.2E-03	8.9E-04	4.4E-03
Au-198	9.4E-05	3.9E-08	9.4E-05
Hg-203	3.3E-04	2.0E-04	8.5E-04
Tl-204	4.0E-06	3.8E-06	1.2E-04
Pb-210	1.9E-03	2.2E-03	5.9E-01
Bi-207	2.6E-03	2.5E-03	3.4E-01
Bi-210	1.2E-04	1.1E-04	7.3E-04

Radionuclide	Conversion factor (mSv/kBq/m²)		
	1st month	2nd month	50 years
Po-210	3.5E-03	2.9E-03	2.0E-02
Ra-226	9.2E-03	9.2E-03	1.9E+00
Ac-227	4.6E-01	4.4E-01	5.1E+01
Ac-228	3.6E-05	1.4E-05	3.0E-04
Th-227	7.7E-03	3.7E-03	1.3E-02
Th-228	4.2E-02	3.9E-02	7.7E-01
Th-230	3.7E-02	3.5E-02	7.5E+00
Th-232	1.9E-01	1.8E-01	4.6E+01
Pa-231	1.2E-01	1.1E-01	6.7E+01
U-232	3.2E-02	3.1E-02	1.2E+01
U-233	8.0E-03	7.6E-03	1.7E+00
U-234	7.9E-03	7.4E-03	1.6E+00
U-235	7.4E-03	7.0E-03	1.5E+00
U-236	7.3E-03	6.9E-03	1.5E+00
U-238	6.8E-03	6.4E-03	1.4E+00
U Dep & Natural	6.8E-03	6.4E-03	1.4E+00
U Enriched	7.9E-03	7.4E-03	1.6E+00
UF6g (U234)	7.9E-03	7.4E-03	1.6E+00
Np-237	2.6E-02	2.5E-02	5.3E+00
Np-239	3.4E-05	6.4E-09	3.4E-05
Pu-236	1.6E-02	1.5E-02	8.0E-01
Pu-238	3.9E-02	3.7E-02	6.6E+00
Pu-239	4.2E-02	4.0E-02	8.5E+00
Pu-240	4.2E-02	4.0E-02	8.4E+00
Pu-241	7.6E-04	7.2E-04	1.9E-01
Pu-242	4.0E-02	3.8E-02	8.0E+00
Am-241	3.5E-02	3.3E-02	6.7E+00
Am-242m	3.2E-02	3.0E-02	6.3E+00
Am-243	3.5E-02	3.3E-02	7.0E+00
Cm-242	4.2E-03	3.5E-03	5.9E-02
Cm-243	3.5E-02	3.3E-02	4.3E+00
Cm-244	2.9E-02	2.7E-02	2.8E+00
Cm-245	5.0E-02	4.7E-02	1.0E+01
Cf-252	1.7E-02	1.5E-02	3.9E-01

3) Example

What is the effective dose received by a person who remains for the first 1 month on ground contaminated with an average of 250 Bq/m^2 of Pu-239 and 1100 Bq/m^2 of Am-241?

Pu-239: $CF_{ground, t}$ = 4.2E-02 (mSv/kBq/m^2).

Am-241: $CF_{ground,t}$ = 3.5E-02 (mSv/kBq/m^2).

$$E_t = C_{ground} \ x \ CF_{ground,t}$$

E_t (Pu-239) = 0.0105 mSv, E_t (Am-241) = 0.0385 mSv

Total effective dose in 1 month for this contamination = 0.049 mSv.

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