ORAU Team **NIOSH Dose Reconstruction Project** Technical Basis Document for the Nevada Test Site – Introduction	Document Number: ORAUT-TKBS-0008-1 Effective Date: 02/04/2004 Revision No.: 00 Controlled Copy No.: ______ Page 1 of 12
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ACRONYMS

DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ft	foot
km^2	square kilometer
m	meter
mi^2	square mile
NIOSH	National Institute for Occupational Safety and Health
NTS	Nevada Test Site
ORAU	Oak Ridge Associated Universities
TBD	Technical Basis Document
TLD	thermoluminescent dosimeter

1.0 INTRODUCTION

In enacting the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), the U.S. Congress officially recognized the hazardous nature of producing and testing nuclear weapons. Under the Act, workers who have developed selected types of cancer (or their survivors) may be entitled to compensation and medical benefits. This program is administered by the U.S. Department of Labor Office of Worker Compensation. The U.S. Department of Health and Human Services National Institute for Occupational Safety and Health (NIOSH) is responsible for determining individual worker doses.

The Act requires the estimation of radiological doses from ionizing radiation received by workers in the nuclear weapons production programs of the U.S. Department of Energy (DOE) and its predecessor agencies (the U.S. Atomic Energy Commission and the Energy Research and Development Agency). Methods for implementing provisions of the Act have been promulgated in Title 42, Part 82, of the Code of Federal Regulations, "Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000".

1.1 PURPOSE

Oak Ridge Associated Universities (ORAU) leads a Team to support NIOSH in conducting this major program. This site profile represents a specific support mechanism to the ORAU Team concerning documentation of historical practices at the Nevada Test Site (NTS). Dose reconstructors can use this profile to evaluate both internal and external dosimetry data for unmonitored and monitored workers and serves as a supplement to, or substitute for, individual monitoring data. This document provides a site profile of the NTS that contains technical basis information to be used by the ORAU Team to evaluate the total occupational radiation dose for EEOICPA claimants.

This document provides supporting technical data to evaluate, with claimant-favorable assumptions, the total Nevada Test Site (NTS) occupational radiation dose that can reasonably be associated with a worker's radiation exposure. This dose results from exposure to external and internal radiation sources from NTS facilities and test operations, to NTS occupationally-required diagnostic X-ray examinations, and to onsite environmental releases. The discussions include evaluation of doses that could have occurred while the worker was not monitored and other forms of missed dose. Over the years, new and more reliable scientific methods and protection measures have been developed. The methods needed to account for these changes are identified in this document.

The doses are evaluated using the NIOSH Interactive RadioEpidemiological Program and the Integrated Modules for Bioassay Analysis computer programs. Information on measurement uncertainties is an integral component of the NIOSH approach. In addition, this document describes the uncertainty evaluation for NTS exposure and dose records.

1.2 SCOPE

The profile comprises six major Technical Basis Documents (TBDs): this Introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dose. Each TBD has an accompanying attachment that provides the critical data for dose reconstruction.

Site Description
The Site Description (ORAU 2003a) discusses NTS site areas, facilities, operations, and processes.

The NTS in southern Nevada encompasses approximately 3,500 km^2 (1,375 mi^2) and was the primary location for the testing of nuclear explosives in the continental United States between 1951 and 1992. Historic testing above or at ground surface included atmospheric testing in the 1950s and 1960s; earth-cratering experiments; and open-air nuclear reactor and rocket testing. Since 1961, testing of nuclear explosive devices has occurred mainly in drilled vertical holes or in mined tunnels.

Aboveground nuclear weapons tests began on January 27, 1951, with the detonation of a 1-kiloton air-dropped weapon over Frenchman Flat. More than 100 atmospheric tests occurred before the signing of the Limited Test Ban Treaty in August 1963. In addition to air drops, atmospheric testing included detonations from towers at heights from 30 to 213 m (100 to 700 ft), detonations on the surface of the ground, and the use of helium-filled balloons to loft weapons 137 to 457 m (450 to 1,500 ft) above the ground.

Since 1963, the United States has conducted all of its nuclear weapons tests underground in accordance with the terms of the Limited Test Ban Treaty. Therefore, complete containment of all nuclear weapons tests was a dominant consideration in nuclear test operations. Various methods were used for emplacing nuclear test devices to contain the explosion. The most common method was to place a test device at the bottom of a vertical drill hole. Another method was to place a test device in a tunnel mined horizontally to a location sufficiently deep to provide containment. There were two types of tests in vertical drill holes: lower yield devices in relatively shallow holes in the Yucca Flats area (Areas 1 through 10) and higher yield devices in deeper holes on Pahute Mesa (Areas 18 through 20).

Post-test drilling of the cavity formed after a detonation in a vertical drill hole was performed to retrieve debris samples. The post-test hole was as small in diameter as possible and was drilled at an angle to allow the drill rig to be positioned safely away from the surface at ground zero. It was possible to encounter high gas pressures in the cavity because the drillback was often performed within a day or two of the detonation.

Reentry and mineback operations related to tests in mined tunnels usually took place within days or weeks of a test. These operations took place in a confined underground environment where personnel actually entered the test tunnel up to the experiment chambers. There were two exposure scenarios during reentry and minebacks. The first scenario was a loss of containment in the drilling or coring operation. The second scenario was the possibility of activation products entering the working areas of the tunnels by migrating through fissures in the rock. Controlled tunnel purging was an intentional release of radioactive material to recover experimental equipment and ventilate test tunnels.

Although over 90% of all nuclear weapons tests occurred as predicted, sometimes the unexpected occurred. In some cases, the failure resulted in the loss of experimental equipment or required the controlled ventilation of a tunnel system to recover equipment. In even more rare cases, the failure resulted in the unintentional release of radioactive material to the atmosphere. Ten tests resulted in unexpected events. Four of those tests resulted in the detection of radioactivity off the NTS: DES MOINES, June 13, 1962; BANEBERRY, December 18, 1970; DIAGONAL LINE, November 24, 1971; and RIOLA, September 25, 1980.

Safety tests evaluated the safety of nuclear weapons in accident scenarios. The safety tests used mixtures of plutonium and uranium dispersed by conventional explosives. Concurrent with and after these detonations, extensive studies were conducted to understand the dispersal and transport of these radionuclides in the environment, including uptake by plants and animals.

A number of activities occurred at the Nuclear Rocket Development Station in Area 25. From 1959 to 1973, the area was used for a series of open-air nuclear reactor, nuclear engine, and nuclear furnace tests and for the High Energy Neutron Reactions Experiment. The goal of the nuclear rocket engine test program was to develop an operational nuclear rocket for space travel. Engine exhaust dispersed radioactive material at the core and cladding degraded during operation of the engine.

Shallow borehole tests occurred between 1960 and 1968. Some of these tests were related to safety studies; others were part of Project PLOWSHARE to determine if nuclear detonations could be used as a method for excavation. The shallow tests resulted in the development of some large ejection craters.

The NTS manages radioactive waste. DOE disposes of bulk low-level waste in seven selected Area 3 subsidence craters that collectively comprise the Area 3 Radioactive Waste Management Site. The activity began in the mid-1960s when DOE began removing scrap tower steel, vehicles, and other large objects that been subjected to atmospheric testing. From 1979 to 1990, large amounts of contaminated soil and other NTS debris were added to the craters. The Area 5 waste management site uses pits and trenches for shallow land burial of low-level waste in standardized packaging.

In addition, DOE adopted greater confinement burial (21 to 40 m [70 to 120 ft] deep) for wastes that are not appropriate for near-surface disposal due to their radioactive exposure levels. Material was disposed from 1984 to 1989. The specific waste types included certain high-specific-activity, low-level waste (for example, fuel rod claddings and sealed sources, transuranic waste, and some classified material).

Occupational Medical Dose

The Occupational Medical Dose TBD (ORAU 2003b) describes the technical aspects of dose reconstruction from medical X-rays administered before employment and periodically thereafter as a condition of employment.

Diagnostic X-ray procedures were a contributor to the occupational radiation exposure of NTS workers. In general, the dose from these exposures was not measured or considered or included as part of the overall occupational exposure of the employee, although it was clearly related. The passage of EEOICPA recognized diagnostic medical X-rays administered in conjunction with routine or special physical examinations required for employment as a valid source of occupational exposure.

Unlike occupational exposures incurred during normal work processes, individual diagnostic medical X-ray exposures were not monitored, necessitating reconstruction of doses acquired in that manner. However, NTS used a unique practice in which employees received film badges on arrival at the Mercury gate for work. In some instances, workers wore those badges during initial employment physicals, which included routine posterior-anterior and lateral chest X-rays. Examination of these badges provided measured doses for those chest X-rays. Based on extensive review of available documentation from 1951 to the present, these X-rays were the only two diagnostic medical radiographic procedures administered in connection with preemployment or regular postemployment medical examinations. Therefore, this analysis evaluated only doses from these two techniques.

A potential problem common to all procedures relates to the conversion of exposure represented by entrance skin exposure to absorbed organ dose, and to changes in the definition of dose and the creation of numerous dose quantities. Over the 50 or so years since the beginning of NTS operations, the quantity known today as exposure has undergone several important conceptual changes, as has the application of the unit of exposure and its associated unit, the roentgen. At one time, the roentgen was used to quantify the dose from electromagnetic radiation and, when this proved confusing and inexact, was defined as exposure dose to distinguish it from the term absorbed dose, which was applicable to any type of radiation. Other dose uncertainties considered include measurement error, variation in applied kilovoltage, variation in beam current, variation in exposure time, and distance from the worker to the source of the X-rays.

Dose estimates to various organs from chest X-rays have also been calculated for the periods from 1951 to 1957 and from 1957 to 2000. The calculated dose takes into account the uncertainty associated with each of the parameters mentioned above. Tables list the doses received by the various organs in the body for convenient reference.

Occupational Environmental Dose

The Occupational Environmental Dose TBD (ORAU 2004c) applies to both monitored and unmonitored workers. The environmental dose is the dose workers receive when working outside the buildings or inside the tunnels on the NTS from inhalation of and submersion in radioactive materials in the air from onsite releases and resuspension of contaminated soils, direct radiation from plumes, and direct exposure to radionuclides incorporated in the soil.

In all, more than 900 nuclear tests have taken place at the NTS as part of the nuclear test program. One result of these tests is that the surface soils in many parts of the NTS contain measurable amounts of several long-lived radionuclides. Almost all of the aboveground tests contaminated the soil near ground zero. Several underground tests vented radioactive material to the surface. A few safety tests, in which a nuclear device was destroyed by conventional explosives, scattered plutonium (and in some cases uranium) over the nearby ground. In addition, there was fallout of radioactive debris from many tests over the northern and eastern parts of the site. This TBD develops methods for estimating potential dose from inhalation of resuspended contaminated soils.

Radiation levels at the NTS have been monitored regularly, and safety officials have identified and fenced off areas where the soil in heavily contaminated. In many other areas, radionuclide levels are not high enough to warrant closing the areas, but they are still above background. This TBD provides estimates of average ambient dose for use by dose reconstructors.

There are several major factors that could affect the accuracy of the average annual intake estimates from soil resuspension. The most important factors include the following:

- Uncertainty in and time-dependent nature of the resuspension factor
- Spatial variations in radionuclide soil concentrations
- Duration of exposures

Each of these factors could result in and over- or underestimations of annual intakes of several orders of magnitude.

Atmospheric weapon and safety tests from 1952 to 1963 resulted in the release of radioactive materials to the atmosphere. Much of this activity was from relatively short-lived radionuclides that decayed in a matter of days or weeks. The volatile radionuclides (such as radioiodines, noble gases, and tritium) were diluted in the atmosphere and transported off the site. However, much of the nonvolatile, long-lived radionuclides settled back into the soils at various locations. Research is currently underway to estimate potential occupational dose that could have been received from these volatile radionuclides during the atmospheric testing phase at the NTS.

In the early 1980s, the Environmental Sciences Department recognized that the buildup of radon daughter concentrations could pose a potential health problem in tunnels on Rainer Mesa and at other locations at the NTS. In 1984, to determine the concentrations of the radon daughters and the effect of environmental conditions on the buildup of these concentrations, scientists conducted radon surveys in G-, T-, and N-Tunnels. Section 4 of the NTS TBD discusses the results of these surveys as well as surveys conducted in 1991 and 1992. Although measurements were periodically performed in the tunnel complexes to ensure adequate worker protection, neither DOE nor its predecessor agencies attempted to quantify or record occupational exposure to radon and its daughters. Therefore, dose reconstructors should adjust the dose of any employee who was a miner or tunnel worker to account for radon. The discussion provides a method for assigning occupational radon exposure.

At the present time, processing of radioactive materials at the NTS includes only laboratory analyses. Handling of these materials includes only the transport and storage of nuclear explosive devices and the operation of radioactive waste management sites for low-level and mixed wastes. Monitoring and evaluation of the various activities indicate that the potential source terms of onsite radiation exposure are tritiated water vapor from drainage containment ponds for E Tunnel in Area 12; onsite radioanalytical laboratories, Area 5 waste management facilities, and other diffuse sources.

Occupational Internal Dose

The Occupational Internal Dose TBD (ORAU 2003d) discusses the internal dosimetry program at the NTS. The primary focus was external dosimetry, particularly during atmospheric testing. This emphasis was based on animal data showing that the internal dose due to inhalation was small in comparison to the external dose. The assumption for atmospheric testing was that external exposure was the controlling factor. If the external dose was controlled, the internal dose would be low. Dose reconstructions performed for military personnel on the site during atmospheric testing determined that this assumption was not valid for individuals in the line of the fallout or in an area where recent or previous tests had been performed and resuspension of residual contamination was a possibility.

Each operation at NTS had a different set of radionuclides of concern at the time of the test and afterward. Radionuclides were identified for NTS locations, including legacy atmospheric, underground, and nuclear reactor/rocket development test areas. Tritium and radioisotopes of cobalt, cesium, iodine, uranium, plutonium, and americium are the principal radioisotopes of concern.

Routine bioassays at NTS included quarterly urine samples, annual whole body counts, and new and terminated employee whole body counts. At present, a large amount of the radiological work at NTS is performed through projects with a specified duration. Routine bioassay monitoring is therefore usually part of the project. A baseline sample is collected as necessary, and post-work samples are collected at the conclusion of the project. If a project requiring bioassay monitoring is expected to last longer than 6 months, bioassay sampling on a quarterly to semi-annual frequency throughout the duration of the project is recommended. An exception to this could be a tritium project with high exposure potential, for which a relatively high frequency of monitoring is required (e.g., weekly to monthly).

The TBD discusses the *in vitro* minimum detectable activities, the analytical methods and the reporting protocols for the radionuclides encountered at the NTS. In addition, the TBD discusses the *in vivo* minimum detectable activities, the analytical methods, and the reporting protocols for the X- and gamma-emitting radionuclides. During atmospheric testing (1951 to 1962), *in vivo* methods of analysis were in place but secondary to other measurements. However, as noted above, the NTS did have a bioassay program that included whole body, thyroid, lung, and wound counting. In 1964, the Los Alamos National Laboratory identified whole body counting for radionuclides that deliver whole body doses. There is no description of where these counts took place; the first reference to onsite capability is 1967. It is assumed that the counts occurred at Los Alamos. It is also assumed that the

University of California-Berkeley and the Lawrence Livermore National Laboratory performed counts at their facilities for their employees that spent time at the NTS. Any records that pertain to REECo employees have been retrieved from other locations for inclusion in the REECo (now BN) record archives.

The records did not state uncertainties for bioassay measurements. This analysis therefore used uncertainties in intake estimates to select the best model and action, which should be taken to reduce errors to the extent reasonably achievable and give the most accurate intake estimate practicable.

Occupational External Dose

The Occupational External Dose TBD (ORAU 2003e) discusses radiation monitoring and control programs at the NTS: personal dosimetry, area monitoring, source term characterization, and measurements of fallout (contamination) dispersion.

During the 1951 to 1958 weapon-testing period, allowable external exposure limits for occupational workers at the NTS were generally consistent with the National Council on Radiation Protection and Measurements recommendations. After the testing moratorium was ended by the Soviet Union in the summer of 1961 and the United States resumed nuclear weapons testing at the NTS, the methods for evaluating external doses to workers evolved over the years as new techniques and equipment have been developed. Concepts in radiation protection also changed.

The TBD describes dose reconstruction parameters, administrative practices, and dosimeter types and technology used for measuring the dose from the types of radiation reported. These parameters are discussed for evaluation of doses measured from exposure to beta, gamma, and neutron radiation.

For nearly three decades, from the start of operations in January 1951 until 1979, personnel dosimeters with photographic emulsions of various types and in various holders (i.e., film badges) were used at the NTS. The term *film badge,* or *film badge dosimeter,* refers to the entire dosimeter issued to personnel, which typically consisted of a dental-sized film packet house in a holder of varying sophistication designed to improve the response characteristics of the film itself. Although a number of different film types were used for dosimetry at the NTS, they generally had similar characteristics and responses to beta and photon radiation. Uncertainties in dosimetry with this film are largely, if not exclusively, the result of external factors rather than differences in the films.

Starting in February 1966, thermoluminescent dosimeters (TLDs) were used at the Nuclear Rocket Development Station as part of the effluent monitoring program. These dosimeters contained a calcium fluoride phosphor bound to a helically wound wire in an evacuated glass tube, and were ideal for the purpose intended but unsuitable for personnel dosimetry. On July 1, 1968, a TLD program was implemented with the cooperation of the Health Services Laboratory of the Idaho Operations Office. The laboratory supplied lithium-fluoride TLD chips and provided experience gained at the National Reactor Testing Station. The first routine use of TLDs at the NTS began in 1970.

With the advent of DOE requirements to restrict personnel exposures to as low as reasonably achievable and with emphasis on accurate dosimetry at low doses, the Environmental Sciences Department personnel began evaluating TLD systems and neutron dosimeters in the early 1980s to replace the then-current film badge and neutron TLD. After evaluating several dosimetry systems, the Panasonic 802 TLD and the neutron TLD were determined to be the best combination for the NTS exposure conditions. They were put into use in January 1987.

The external dosimetry discussion includes sources of bias, workplace radiation field characteristics, and the responses of the different beta/gamma and neutron dosimeters in the workplace. An evaluation of the original recorded doses based on the established parameters described in the TBD should provide the best estimate of dose for individual workers with the least overall uncertainty.

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GLOSSARY