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National Emission Standards for Hazardous Air Pollutants – Radionuclide Emissions Calendar Year 2019

June 2020

Nevada National Security Site
&
North Las Vegas Facility

Prepared for

U.S. Department of Energy,
National Nuclear Security Administration
Nevada Field Office
Under Contract Number
DE-NA0003624

Prepared by

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NEVADA NATIONAL NNSS SECURITY SITE
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National Nuclear Security Administration

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Certification

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment. See 18 U.S.C. 1001.

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) operates the Nevada National Security Site (NNSS) and the North Las Vegas Facility (NLVF). From 1951 through 1992, the NNSS was the continental testing location for U.S. nuclear weapons. The release of radionuclides from NNSS activities has been monitored since the initiation of atmospheric testing. After 1962, testing was limited to underground detonations, which greatly reduced radiation exposure to the public. Since the end of nuclear testing in 1992, radiation monitoring has focused on detecting airborne radionuclides from historically contaminated soils because this source dominates the potential offsite dose. These radionuclides are derived from re-suspension of soil (primarily by wind) and emission of tritium-contaminated soil moisture through evapotranspiration. Low amounts of legacy-related tritium are also emitted to air at the NLVF, an NNSS support complex in North Las Vegas.

To protect the public from harmful levels of manmade radiation, the Clean Air Act, National Emission Standards for Hazardous Air Pollutants (NESHAP), specifically the National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities (2019) limits the release of radioactivity from a DOE facility to that which would cause 10 millirem per year (mrem/y) effective dose equivalent (EDE) to any member of the public. This limit does not include radiation unrelated to NNSS activities. Unrelated doses could come from naturally occurring radioactive elements, from sources such as medically or commercially used radionuclides, or from sources outside of the United States, such as Japan's Fukushima nuclear power plant, which was damaged in 2011.

NNSA/NFO demonstrates compliance with the NESHAP limit by reporting environmental measurements of radionuclide air concentrations at critical receptor locations on the NNSS. This method was accepted by the U.S. Environmental Protection Agency (EPA) in 2001 (EPA 2001a) and has been the primary method used to demonstrate compliance with the 40 CFR 61.92 dose standard since 2005. Six locations on the NNSS have been established to act as critical receptor locations to demonstrate compliance with the NESHAP limit. These locations are actually pseudo-critical receptor stations because no member of the public resides at these onsite locations. Compliance is demonstrated if the measured annual average concentration is less than the NESHAP Concentration Level (CL) for Environmental Compliance listed in Table 2 of 40 CFR 61, Appendix E. For multiple radionuclides, compliance is demonstrated when the sum of the fractions (determined by dividing each radionuclide's concentration by its CL and then adding the fractions together) is less than 1.0. A second method of demonstrating compliance was use of the EPA-approved air transport model, called the Clean Air Package 1988 (CAP88-PC). This model was used to calculate the effected dose equivalent to the maximally exposed individual attributed to NNSS air emissions. CAP88-PC was also used to calculate the population dose, or the collective EDE (expressed as person-rem [roentgen equivalent man] per year [person-rem/yr]) for all individuals combined who reside within 80 km of NNSS emission sources.

In 2019, the potential dose from radiological emissions to air from both current and past NNSS activities was well below the 10 mrem/y dose limit. This is demonstrated by both the air sampling data collected at critical receptor air monitoring stations and CAP88-PC modeling. The average concentrations of radioactivity at air critical receptor stations ranged from 0.2% to a maximum of 4.6% of the allowed NESHAP limit. CAP88-PC modeling of all 2019 NNSS radionuclide emissions showed the maximally exposed individual to be in Amargosa Valley and this individual received a potential dose of 0.057 mrem/y. The collective dose was calculated to be 0.29 person-rem/year for the 499,500 people who lived within 80 km (50 mi) of NNSS emission sources.

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List of Acronyms and Abbreviations

Am	americium
Ar	argon
ARL/SORD	Air Resources Laboratory, Special Operations and Research Division
Ba	barium
BEEF	Big Explosives Experimental Facility
Br	bromine
C	carbon
°C	degrees Celsius
CAP88-PC	Clean Air Package 1988 (EPA software program for estimating doses)
Ce	cerium
CFR	Code of Federal Regulations
Ci	curie(s)
CL	Concentration Level
cm	centimeter(s)
Co	cobalt
Cs	cesium
CY	calendar year
d	day(s)
DAF	Device Assembly Facility
DOE	U.S. Department of Energy
DPFF	Dense Plasma Focus Facility
DRA	Desert Rock Meteorological Observatory
DU	depleted uranium
E	east
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
Eu	europium
ft^3/min	cubic feet per minute
h	hour(s)
^3H	tritium
HEPA	high efficiency particulate air
HTO	tritiated water in the form of $^3H^3HO$ or ^3HHO
I	iodine if with atomic mass superscript
JASPER	Joint Actinide Shock Physics Experimental Research
K	potassium
km	kilometer(s)
km^2	square kilometer(s)
Kr	krypton
L	liter(s)

List of Acronyms and Abbreviations (continued)

La	lanthanum
LLW	low-level waste
m	meter(s)
mCi	millicurie(s)
mCi/y	millicurie(s)/year
MEDA	Meteorological Data Acquisition
MEI	maximally exposed individual
MIDNET	Meteorological Integrated Data Network
min	minute(s)
Mo	molybdenum
mrem/y	millirem per year
µrem/y	microrem per year
m/s	meter(s) per second
N	north or nitrogen (nitrogen if with atomic mass superscript)
Nb	niobium
NCERC	National Criticality Experiments Research Center
Nd	neodymium
NESHAP	National Emission Standards for Hazardous Air Pollutants
NLVF	North Las Vegas Facility
NNSA/NFO	DOE, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NOAA	National Oceanic and Atmospheric Administration
NPTEC	Nonproliferation Test and Evaluation Complex
NTTR	Nevada Test and Training Range
O	oxygen
pCi	picocurie(s)
pCi/L	picocurie(s) per liter
pCi/m^3	picocurie(s) per cubic meter
Pm	promethium
Pr	praseodymium
Pu	plutonium
RIDP	Radionuclide Inventory and Distribution Program
rem	roentgen equivalent man
Rh	rhodium
RNCTEC	Radiological/Nuclear Countermeasures Test and Evaluation Complex
Ru	ruthenium
RWMC	Radioactive Waste Management Complex
RWMS	Radioactive Waste Management Site
s	second(s)
S	south
Sb	antimony
Sm	samarium
Sn	tin

List of Acronyms and Abbreviations (continued)

Sr	strontium
STAR	Stability Array (grouping of meteorological data)
Te	tellurium
TRU	transuranic (nuclides with atomic numbers greater than uranium)
U	uranium
UCC	Yucca Flat Meteorological Observatory
UGTA	Underground Test Area
UNESE	Underground Nuclear Explosion Signatures Experiment
W	west
Xe	xenon
y	year(s)
Zr	zirconium

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Report Information

U.S. Department of Energy
National Nuclear Security Administration
Nevada Field Office
Air Emissions Annual Report
(under Subpart H, Title 40 Code of Federal Regulations [CFR] 61.94)
Calendar Year (CY) 2019

Site Name: Nevada National Security Site

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SECTION I
FACILITY INFORMATION

SITE DESCRIPTION

The Nevada National Security Site (NNSS) is operated by the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) as the site for maintaining and enhancing the safety, security, reliability, and performance of the U.S. nuclear weapons stockpile; reducing global danger from weapons of mass destruction; and responding to nuclear and radiological emergencies in the U.S. and abroad. The NNSS is also an operational site for environmental restoration, low-level radioactive waste management, and groundwater characterization activities. Located in Nye County, Nevada, the site's southeast corner is about 105 kilometers (km) northwest of the major population center, Las Vegas, Nevada. The NNSS covers about 3,523 square kilometers (km^2) and is 46 to 56 km east to west and 64 to 88 km north to south. The NNSS is surrounded, except on the south side, by the Nevada Test and Training Range (NTTR), a public exclusion area that provides another 24 to 104 km between the NNSS and publicly accessible land (Figure 1).

The NNSS is characterized by desert valley and Great Basin mountain topography, with climate, flora, and fauna typical of the southwest deserts. Based on the most recent population estimates (U.S. Census Bureau 2020, Clark County Department of Comprehensive Planning 2019), there were 503,500 people residing within 80 km of the NNSS boundary. Of these, 499,500 people were within 80 km of NNSS emission sources. The distribution of this population is concentrated in the metropolitan areas of Las Vegas and North Las Vegas (90%) to the southeast and in the town of Pahrump (7%) to the south (Figure 1). These more populated areas drive the overall average population density up to about 11.2 person/km^2, but the vast majority of the area within 80 km of the NNSS is uninhabited. The nearest populated location to the NNSS boundary is the north end of Amargosa Valley, which extends to within 3.4 km of the southwest corner of the NNSS. Two mines are also relatively near the boundaries of the NNSS: the American Silica mine, 2.7 km east of the southeast edge of the NNSS, and the Cinder Cone Pit mine, 5.5 km west of the southwest corner of the NNSS. The American Silica mine was not in operation in 2019 but is still identified on maps for reference.

One dairy operated within 80 km of the NNSS in 2019. It is located in Amargosa Valley at a distance of about 16.1 km from the NNSS boundary. Agriculture around the NNSS is sparse and consists primarily of alfalfa fields, which are found mainly in Amargosa Valley, Pahrump, Penoyer Farm, Reed's Ranch, and locations between Alamo and Hiko. There were also one honey production and two winery businesses operating in Pahrump in 2019. These are about 44 km south of the NNSS boundary. One 60-acre farm in Las Vegas, 73.3 km east-southeast of the NNSS, operated in 2019. This farm sells produce directly to the public. Sparse livestock production may occur throughout the area around the NNSS on a relatively small scale.

The North Las Vegas Facility (NLVF) is an 80-acre complex composed of buildings that house much of the NNSS project management; diagnostic development; and testing, design, engineering, and procurement operations. This facility is located along Losee Road in the city of North Las Vegas and is surrounded on the north, south, and east by general industrial zoning. The western border separates the property from fully developed, single-family residential-zoned property.

SOURCE DESCRIPTION

In 1950, the now-named NNSS was established as the primary location for testing the nation's nuclear explosive devices. Such testing took place from 1951 to 1992. Historical testing included (1) atmospheric testing in the 1950s and early 1960s, (2) underground testing between 1951 and 1992, and (3) open-air nuclear reactor and rocket engine testing between 1959 and 1973. No nuclear tests have been conducted since September 23, 1992 (U.S. Department of Energy [DOE] 2013). The environmental legacy of nuclear weapons and other testing on the NNSS is a major source of radionuclides that are released into the air. They are characterized as non-point (diffuse) sources and include (1) areas of radioactively contaminated surface soils, (2) contaminated groundwater

that is pumped or flows naturally to the surface, (3) radioactive waste storage and burial sites, and (4) radiologically contaminated structures and materials being decommissioned, demolished, and/or managed.

Surfaces contaminated with plutonium (Pu), americium (Am), tritium (^{3}H), and fission and activation products from past nuclear device safety, atmospheric, or cratering test activities could become sources of radionuclide exposure to the public if the radionuclides were to be re-suspended, for example, through evaporation or transpiration of ^{3}H in water, by windy conditions, surface cleanup, construction, vehicular travel, or similar process for radionuclides associated with particulates. In 1981, DOE began a project known as the Radionuclide Inventory and Distribution Program (RIDP). After five years of field work and three years of data analysis, the result was a report that identified the inventory and described the distribution of radionuclides in the soil in parts of the NNSS affected by NNSS operations (DOE 1991) (Table 1). The inventory includes an estimate of the curies (Ci) of the manmade radionuclides detected and reported by the RIDP. Though the inventory includes cobalt-60 (^{60}Co), strontium-90 (^{90}Sr), cesium-137 (^{137}Cs), and the europium (Eu) isotopes ^{152}Eu, ^{154}Eu, and ^{155}Eu, their concentrations in air samples are generally below detection levels and collectively contribute less than 10% to total dose, which is the threshold for required measurement per Title 40 Code of Federal Regulations (CFR) 61.93. Figure 2 shows areas of elevated exposure rates due to radionuclides in NNSS soils as measured by an aerial survey conducted in 1994 (Hendricks and Riedhauser 1999).

Table 1. Inventory of Manmade Radionuclides in NNSS Surface Soil[a]

	Radionuclide inventory (Ci)[b]								
Area[c]	^{60}Co	^{90}Sr	^{137}Cs	^{152}Eu	^{154}Eu	^{155}Eu	^{238}Pu	$^{239+240}$Pu	^{241}Am
1	0.02	7.37	4.47	3.31	0.01	0.01	5.15	23.98	6.06
2	0.02	22.60	12.18	3.09	0.00	0.01	6.81	21.98	4.65
3	0.02	16.21	6.09	3.97	0.01	0.01	2.45	36.97	7.56
4	0.03	6.39	6.09	2.01	0.00	0.00	10.29	39.97	9.73
5	0.01	0.44	0.20	2.21	0.02	0.00	0.08	4.80	0.98
6	0.00	1.72	1.42	0.00	0.00	0.00	2.61	8.39	2.34
7	0.02	4.52	2.64	4.85	0.02	0.00	0.48	15.99	3.47
8	0.12	12.28	21.31	0.97	0.00	0.01	6.34	109.91	25.65
9	0.01	6.39	4.42	5.07	0.02	0.00	1.74	88.92	11.64
10	0.20	27.02	42.63	0.49	0.03	0.07	15.05	109.91	27.55
11	0.00	0.15	0.25	0.00	0.00	0.00	0.40	28.98	5.63
12	0.02	8.35	10.15	0.00	0.00	0.00	6.73	38.97	8.78
15	0.01	10.81	9.64	0.00	0.00	0.00	6.18	62.95	13.03
16	0.00	1.82	1.47	0.00	0.00	0.00	1.19	3.70	0.98
17	0.02	9.33	7.61	0.00	0.00	0.00	3.56	17.98	4.21
18	0.01	8.35	5.07	0.24	0.01	0.01	4.43	99.92	26.70
19	0.02	15.23	18.27	0.00	0.00	0.00	25.34	139.88	32.03
20	0.16	2.11	2.79	2.87	0.15	0.07	23.76	40.97	25.45
25	0.00	0.05	0.10	0.09	0.00	0.00	0.00	0.00	0.00
30	0.02	0.64	0.76	0.15	0.01	0.00	3.56	13.99	4.25

(a) Source of inventory from DOE (1991) and includes radionuclides in soil within 0–30 centimeters (cm) of the surface with most activity in the top 5 cm.
(b) Decay corrected to the middle of calendar year 2019 (July 2, 2019), with ingrowth of ^{241}Am from ^{241}Pu included.
(c) Areas not listed have negligible amounts of manmade radionuclides in surface soil.

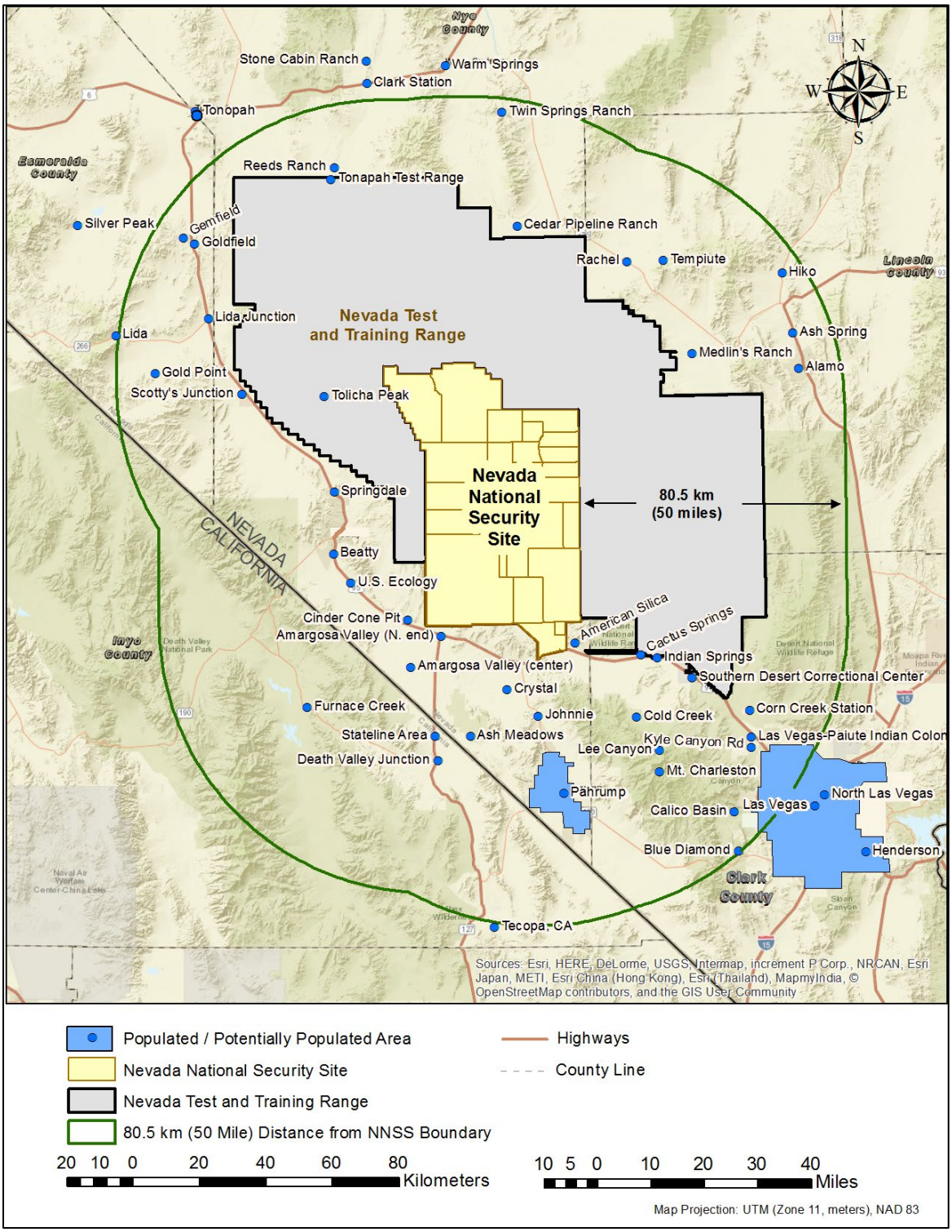

Figure 1. NNSS and Surrounding Populated Area

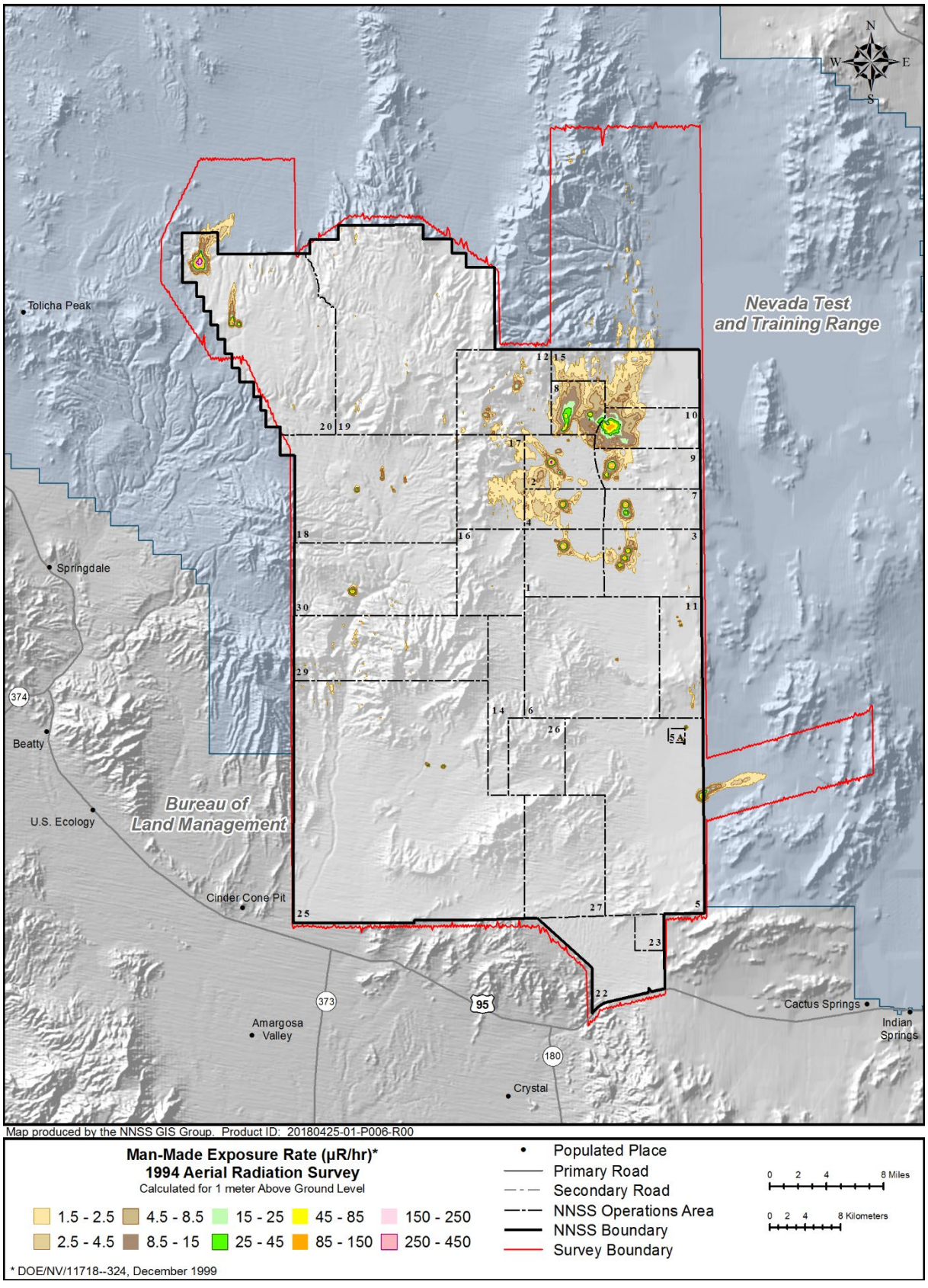

Figure 2. Distribution of Elevated Exposure Rates from Radionuclides in NNSS Soils

Current missions of the NNSS are to help ensure the security of the United States and its allies by supporting the stewardship of the nuclear deterrent stockpile, providing emergency response capability and training, and contributing to key nonproliferation and arms control initiatives. Activities include (1) conducting high-hazard operations in support of defense-related nuclear and national security experiments; (2) providing support for homeland security activities, national security, and nonproliferation technology development and research; (3) characterizing and remediating the environmental legacy of past nuclear testing; and (4) managing and disposing of radioactive wastes. A few programs and experiments at the NNSS use or handle radioactive materials. In all such locations, radioactive materials are controlled in accordance with 10 CFR Part 835, "Occupational Radiation Protection" (2019). The primary locations that have key NNSA/NFO missions which may have unsealed radioactive material and are potential sources for radiological air emissions are shown in Figure 3. Radionuclides potentially present at these locations include various isotopes of Pu, Am, and U, as well as ^{3}H, ^{60}Co, ^{137}Cs, and various short-lived activation and fission products. Radioactive emissions are not necessarily produced from these locations in a given year, but all have the potential for radioactive emissions. The key locations and programs that are potential NNSS sources are listed by general organization category below.

- Stockpile Stewardship, Science, and Experimentation
    - Device Assembly Facility (DAF)
        - National Criticality Experiments Research Center (NCERC)
    - Dense Plasma Focus Facility (DPFF)
    - High Explosive Facilities
        - Big Explosives Experimental Facility (BEEF)
    - Joint Actinide Shock Physics Experimental Research (JASPER)
    - U1a Complex
- Nonproliferation, Counterterrorism, and Incident Response
    - Nonproliferation Test and Evaluation Complex (NPTEC)
    - Radiological/Nuclear Countermeasures Test and Evaluation Complex (RNCTEC)
    - T1 Training and Exercise Area
    - Tumbleweed Test Range
    - Tunnel operations
- Environmental Restoration and Waste Operations
    - Environmental Restoration
    - Radioactive Waste Management Complex (RWMC)
        - Area 3 Radioactive Waste Management Site (RWMS)
        - Area 5 RWMC
    - Underground Test Area (UGTA) Activity
- Mission Support
    - Buildings housing support activities where radioactive material may be surveyed, processed, and/or analyzed include 23-180, 23-600, 23-650, 23-652, and 23-703. All of these are in Mercury in Area 23 (Figure 3). Handling of radioactive material in these buildings is limited and consists primarily of handling environmental samples and laboratory standards containing radioactive material. Although the amounts of radioactive material in the environmental samples and laboratory standards are low, and therefore the potential emissions from them are also very low, they are still included as sources.

All facilities and activities from which radionuclides were known to be released to air in calendar year (CY) 2019 are listed in Section II, Table 2, and their source information is listed in Appendix A, Table A.1.

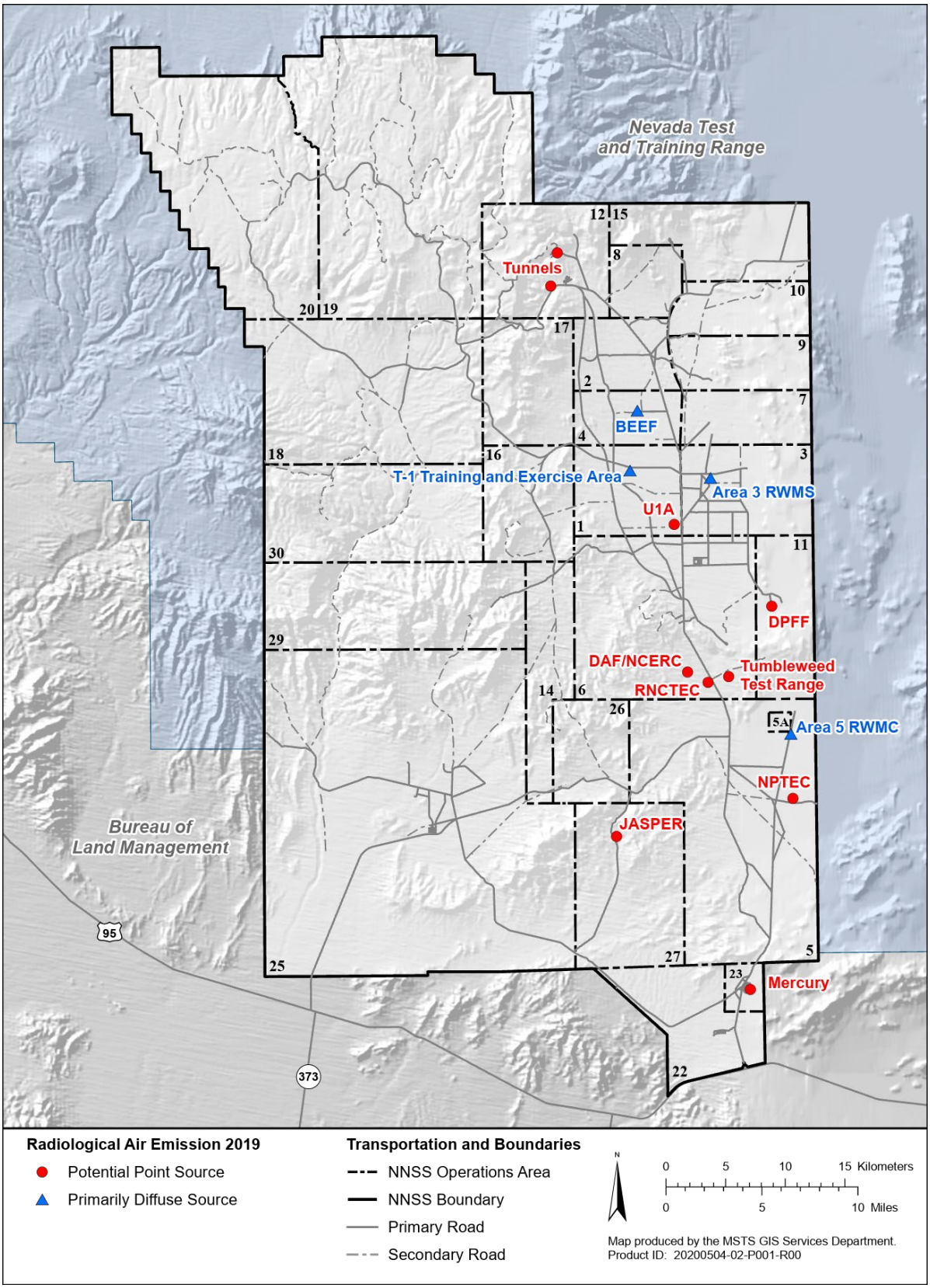

Figure 3. Primary Facilities or Projects with Potential to Release Radionuclides to Air

SECTION II
AIR EMISSIONS DATA

Locations and operations from which radionuclides were released to the atmosphere during CY 2019 are listed in Table 2, and their source information is in Appendix A. Their locations are displayed in Figure 4. Releases for the year are grouped into five general source categories: (1) Legacy Contamination Sites; (2) Stockpile Stewardship, Science, and Experimentation; (3) Nonproliferation, Counterterrorism, and Incident Response; (4) Environmental Restoration and Waste Operations; and (5) Mission Support. CY 2019 emission sources by category are described below.

Legacy Contamination Sites

The environmental legacy of nuclear weapons and other testing on the NNSS is the predominant source of radionuclides that are released into the air. They are generally characterized as non-point (diffuse) sources and include:

Weapon Test and Plowshare Soil Contamination Sites

Three general soil contamination locations are listed for emission sources in this category. Two of them, Sedan and Schooner, are craters from the Plowshare program, which used nuclear devices to demonstrate their ability to excavate large amounts of earth. They are specifically listed separately from other test locations because they dominate the legacy contamination sites for ^{3}H emissions. The derivation of ^{3}H emission estimates from these locations is described in Appendix B. The third general location, referred to as "Grouped Area Sources," is a grouping of all large areas impacted by past nuclear testing on the NNSS. This grouping is used to report emissions of radionuclides in particulate form due to soil resuspension caused by wind. The derivation of this emission is described in Appendix C.

Emanation from Building Materials

At the NLVF, parts of the Building A-01 basement were contaminated with ^{3}H in 1995. Emanation of tritiated water in the form of $^{3}H^{3}HO$ or ^{3}HHO (collectively referred to as HTO) from these building materials has persisted at continually decreasing levels. These emissions are exhausted from the building through the ventilation system. A description of the incident and the potential effective dose equivalent (EDE) for offsite exposure during CY 2019 are presented in Appendix D.

The 1995 ^{3}H contamination of the NLVF Building A-01 basement also affected an inactive radiation source well that had since been filling with water due to the soil bottom in the well and a rise in groundwater. This source well was sealed in 2001 and a pump was installed to remove the residual ^{3}H contaminated water. After more than 15 years of pumping, average tritium concentrations are not detectable with standard analyses. The State of Nevada approved disposing of this water through discharges under the NLVF DeMinimis General Permit. There were no tritium emissions from this source in CY 2019.

Stockpile Stewardship, Science, and Experimentation

The NNSS provides unique resources to maintain the integrity of the United States' nuclear weapons stockpile through weapons testing without nuclear detonation. Nuclear Asset Operations supports this mission through its nuclear and high-hazard facility management.

Certain experiments have the potential for radioactive emissions. Primary locations for such emissions are DAF in Area 6, NCERC (located within the DAF) in Area 6, DPFF in Area 11, U1a in Area 1, BEEF in Area 4, and JASPER in Area 27.

During CY 2019, BEEF and DPFF were the only locations known to have radioactive emissions. Also, conservatively calculated potential air emissions from NCERC are included as a source for CY 2019.

Nonproliferation, Counterterrorism, and Incident Response

This category can be generally described as global security activities conducted to strengthen national security by providing real-world testing, evaluation, and training venues. Certain activities have the potential for radioactive emissions. The primary locations for this are the T1 Training and Exercise Area in Area 1, RNCTEC in Area 6, NPTEC in Area 5, the Tumbleweed Test Range in Area 6, and tunnel complexes primarily in Area 12. Certain experiments using radioactive materials may also be conducted in remote locations of the NNSS.

There were no locations in this category from which radionuclides were known to be released during CY 2019.

Environmental Restoration and Waste Operations

Environmental Restoration

Environmental Restoration Corrective Action Site 12-59-01, E-Tunnels, has water contaminated from historical nuclear weapons testing flowing into collection ponds (E-Tunnel Ponds) in Area 12. The only radiological contaminant that produces a measurable air emission is ^{3}H evaporating as HTO. Calculation of this emission source for CY 2019 is described in Appendix E.

An Environmental Restoration cleanup project was started during CY 2017 at the Clean Slate site on the Tonopah Test Range. This work continued through CY 2019. Environmental monitoring / reporting is conducted by Sandia National Laboratories (http://www.sandia.gov/news/publications/environmental_reports/).

There were no Environmental Restoration demolitions or cleanup projects conducted on the NNSS during CY 2019 that had a potential for radionuclide emissions to air.

Underground Test Area (UGTA) Activity

UGTA activities include the task of characterizing the aquifers at sites of past underground nuclear tests. To characterize the groundwater regime, suitable wells are drilled and existing wells re-completed and sampled as determined by hydrologists. During these drilling and sampling operations, water is pumped to the surface. This water is then available for evaporation. Again, the only contaminant producing a measurable air emission from this evaporating water is ^{3}H as HTO. During CY 2019, water containing ^{3}H was pumped from the following wells:

- RNM #2
- UE-5n
- ER-20-5-1
- ER-20-5-3
- U-20n PS 1DDh
- UE-20n1

These well locations are displayed in Figure 4. Calculation of the ^{3}H emission from water pumped from them is described in Appendix E.

Waste Operations

The Area 3 RWMS and the Area 5 RWMC are used for the disposal of packaged, dry, low-level waste which is buried in pits and trenches. The Area 5 RWMC also has facilities for waste examination and repackaging activities, the accumulation of mixed waste, and the storage of transuranic (TRU) and mixed TRU wastes. Concrete pads are used for temporary storage of these wastes. The only radioactive emission detected by the various types of samplers located downwind of these sites and attributed to waste operations was ^{3}H as HTO in atmospheric moisture. Calculation of the ^{3}H source term for these emissions in CY 2019 is described in Appendix B.

Mission Support

Locations with laboratories as described in Section I have the potential to emit low quantities of radionuclides from handling or processing contaminated material (primarily samples) or from the preparation of ^{3}H standards that are used for quality assurance purposes. Also, the Radiological Control Department has the responsibility of conducting receipt surveys of any radioactive materials arriving at the NNSS. If packaging is damaged, materials must be handled during repackaging, which creates the potential for low-level air emissions. These activities generally take place at Radioactive Materials Control, Building 23-180. Of these support buildings, only operations in Building 23-652 were known to use unsealed radioactive materials in CY 2019; therefore, it was the only location in this category listed as being an emission source in CY 2019.

Radionuclide emissions from each CY 2019 source were characterized by one of the following methods:

- Facility- or project-reported radionuclide emissions based on operations
- Identifying the radionuclide inventory and determining losses of radionuclides that were released to the environment using 40 CFR 61 Appendix D emission factors
- Measuring the HTO concentrations in liquid effluents discharged and proceeding as if all the effluent evaporates over the course of the year to become an air emission
- Using re-suspension calculations
- Using a combination of environmental measurements and the Clean Air Package 1988 (CAP88-PC) air dispersion model (EPA 2014) to calculate the emissions

Distances and directions from all CY 2019 emission sources to the nearest offsite locations of interest are listed in Table 2. Distances ranged from 20 to 72 km from NNSS emission sources and from 0.1 to 0.85 km from the NLVF emission source.

Total CY 2019 emissions, by radionuclide, are shown in Table 3 for the NNSS and in Table 4 for the NLVF. Radionuclide emissions by source are shown in Table 5. The source type, emission control (for example, high efficiency particulate air [HEPA] filters), and description of the nature of each emission are listed in Table A.1 of Appendix A. Appendices B through E describe the methods used to determine CY 2019 emissions.

Radionuclides making up about 55% of the total activity emitted from the NNSS in CY 2019 have very short half-lives. These range from seven seconds for nitrogen-16 to 15.3 minutes for metastable xenon-135. Due to these short half-lives, almost all of the activity is lost due to physical decay over the time it takes to travel the long distances to offsite receptors (Table 2).

Table 2. CY 2019 Radionuclide Emission Sources and Distance to Offsite Locations

Emission Source		Distance[a] and Direction[b] to Nearest Offsite Locations		
		Offsite Residence	Offsite Business/Office	Offsite School
Legacy Contamination Sites	Sedan	51 km ENE (Medlin's Ranch)	58 km NNE (Rachel)	72 km WSW (Beatty)
	Schooner	36 km WSW (Sarcobatus Flat)	20 km WSW (Tolicha Peak)	55 km SSW (Beatty)
	Grouped Area Sources – All NNSS Areas	Various locations ranging from 20 to 74 km		
	Building A-01, basement, NLVF	0.6 km W (N Las Vegas)[c]	0.1 km (at north fence of NLVF)	0.85 km W (N Las Vegas)[c]
Stockpile Stewardship, Science, and Experimentation	BEEF	29 km ENE (NTTR)	29 km ENE (NTTR)	64 km WSW (Beatty)
	DPFF	35 km NNE (NTTR)	35 km NNE (NTTR)	49 km SSE (Indian Springs)
	NCERC	42 km SW (Amargosa Valley)	42 km SW (Amargosa Valley)	49 km SE (Indian Springs)
Environmental Restoration and Waste Operations	E-Tunnel Ponds	53 km WSW (Springdale)	55 km WNW (Tolicha Peak)	62 km SW (Beatty)
	UGTA Wells	34 km SE (Cactus Springs)	38 km SE (Indian Springs)	38 km SE (Indian Springs)
	Area 3 RWMS	56 km SW (Amargosa Valley)	56 km SW (Amargosa Valley)	61 km SSE (Indian Springs)
	Area 5 RWMC	36 km SE (Cactus Springs)	40 km SE (Indian Springs)	40 km SE (Indian Springs)
Mission Support	Building 23-652	24 km SW (Crystal)	24 km SW (Crystal)	30 km (Indian Springs)

(a) Distance is shown in km. For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.
(c) City of North Las Vegas.

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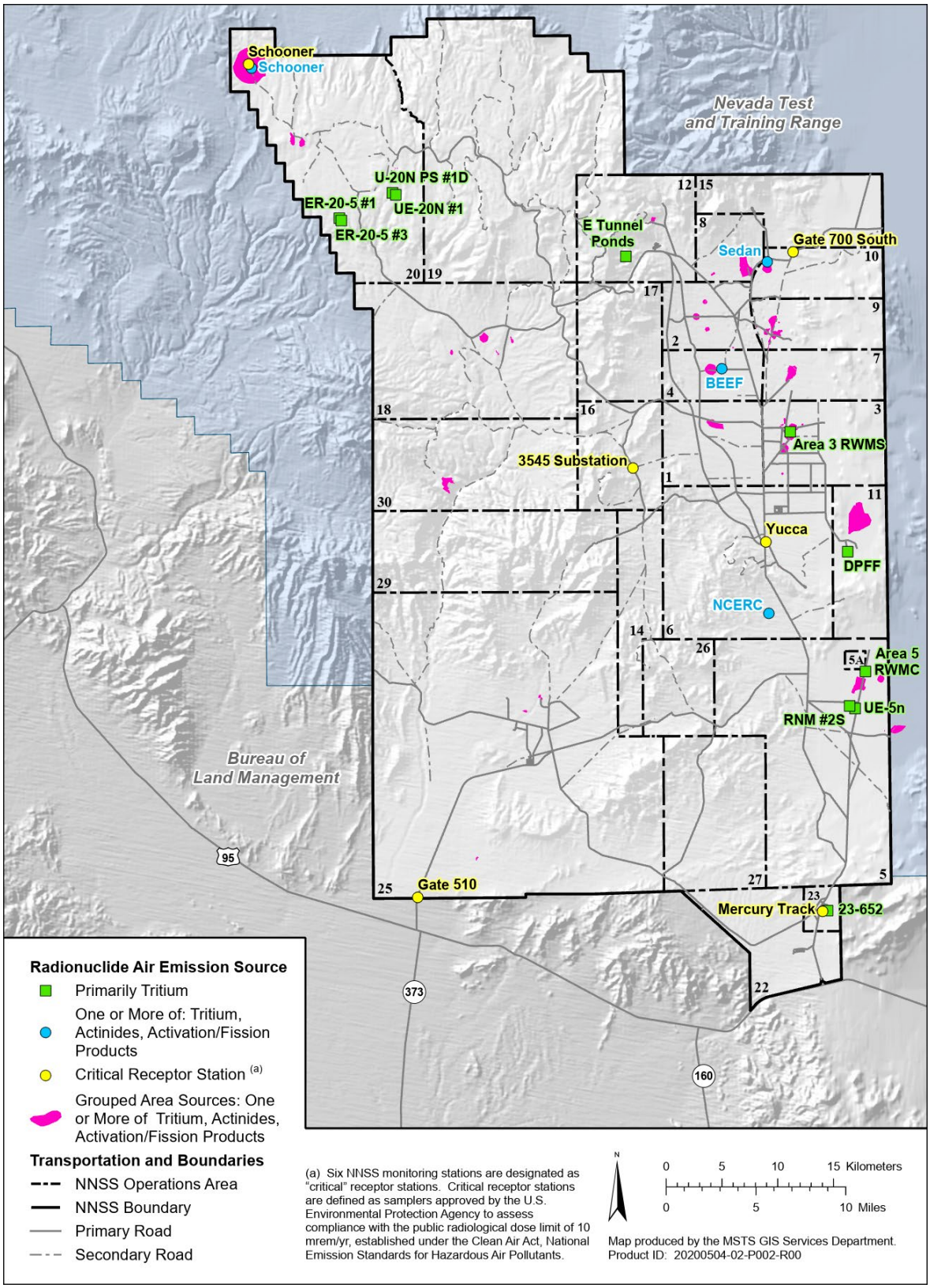

Figure 4. Sources of Radiological Air Emissions and Critical Receptor Air Monitoring Stations on the NNSS in CY 2019

Table 3. Total Estimated NNSS Emissions for CY 2019

Radionuclide[(a)]	Symbol	Half-life	Total Quantity (Ci)	Radionuclide[(a)]	Symbol	Half-life	Total Quantity (Ci)
Tritium	^{3}H	12.32 years (y)	6.89E+02	Xenon-133	^{133}Xe	5.24 d	1.13E-01
Carbon-14	^{14}C	5,730 (y)	8.84E-06	metastable Xenon-133	^{133m}Xe	2.19 d	1.64E+00
Nitrogen-16	^{16}N	7.1 seconds (s)	1.27E+00	Xenon-135	^{135}Xe	9.14 h	2.26E+01
Oxygen-19	^{19}O	26.5 s	2.25E-03	metastable Xenon-135	^{135m}Xe	15.29 m	1.49E+02
Argon-41	^{41}Ar	109.6 minutes (min)	4.86E-01	Cesium-134	^{134}Cs	2.064 y	4.82E-08
Cobalt-60	^{60}Co	5.27 y	2.33E-04	Cesium-137	^{137}Cs	30.17 y	5.04E-02
Bromine-85	^{85}Br	2.9 min	7.95E+02	Barium-140	^{140}Ba	12.75 d	6.45E-01
Krypton-85	^{85}Kr	10.76 y	9.49E-05	Lanthanum-140	^{140}La	1.68 d	4.90E-08
metastable Krypton-85	^{85m}Kr	4.48 hours (h)	9.12E+00	Cerium-141	^{141}Ce	32.50 d	2.35E-04
Strontium-90	^{90}Sr	28.79 y	5.17E-02	Cerium-144	^{144}Ce	285.1 d	2.50E-05
Zirconium-95	^{95}Zr	64.02 d	1.32E-09	Praseodymium-144	^{144}Pr	17.28 m	5.88E-06
Niobium-95	^{95}Nb	34.99 d	2.42E-09	Neodymium-147	^{147}Nd	10.98 d	2.65E-09
metastable Niobium-95	^{95m}Nb	3.61 d	2.53E-10	Promethium-147	^{147}Pm	2.62 y	3.04E-11
Molybdenum-99	^{99}Mo	2.75 d	2.91E-08	Promethium-149	^{149}Pm	53.08 h	6.27E-09
Ruthenium-103	^{103}Ru	39.25 d	1.08E-09	Promethium-151	^{151}Pm	28.4 h	4.75E-09
Rhodium-106	^{106}Rh	29.8 s	1.22E-05	Samarium-151	^{151}Sm	90 y	1.71E-05
metastable Tin-121	^{121m}Sn	43.9 y	3.17E-10	Samarium-153	^{153}Sm	46.5 h	1.02E-01
Antimony-124	^{124}Sb	60.2 d	2.42E-06	Europium-152	^{152}Eu	13.54 y	9.24E-03
Antimony-125	^{125}Sb	2.76 y	8.67E-05	Europium-154	^{154}Eu	8.59 y	8.45E-05
Tellurium-132	^{132}Te	3.2 d	1.89E+00	Europium-155	^{155}Eu	4.76 y	9.13E-05
Iodine-129	^{129}I	15,700,000 y	2.34E-10	Depleted Uranium	DU	>159,200 y	5.22E-02
Iodine-131	^{131}I	8.02 d	5.47E-01	Plutonium-238	^{238}Pu	87.7 y	3.98E-02
Iodine-133	^{133}I	20.8 h	9.94E+00	Plutonium-239+240	$^{239+240}Pu$	24,110 y	2.86E-01
Iodine-135	^{135}I	6.57 h	3.04E+01	Americium-241	^{241}Am	432 y	6.96E-02
metastable Xenon-131	^{131m}Xe	11.84 d	4.02E-03				

Note: This table includes conservative point and diffuse source release estimates.

(a) Includes all radionuclides with reasonable emission estimates available. Only two of these radionuclides ($^{239+240}Pu$ and ^{241}Am) would contribute ≥ 10% of the potential EDE to the maximally exposed individual (MEI) (threshold for required measurement per 40 CFR 61.93(5)(iii)).

Table 4. Total Estimated NLVF Emissions for CY 2019

Radionuclide	Total Quantity (Ci)
^{3}H	2.35E-03

Table 5. Summary of CY 2019 Air Emissions Data by Source

Emission Source[a]		Emission Control	Radionuclide	Quantity (Ci/y)	Radionuclide	Quantity (Ci/y)
Legacy Contamination Sites	Sedan[b]	None	^{3}H	9.76E+00		
	Schooner[b]	None	^{3}H	7.70E+00		
	Grouped Area Sources – All NNSS Areas[c]	None	^{60}Co	2.33E-04		
			^{90}Sr	5.10E-02		
			^{137}Cs	4.97E-02		
			^{152}Eu	9.24E-03		
			^{154}Eu	8.45E-05		
			^{155}Eu	5.83E-05		
			^{238}Pu	3.98E-02		
			$^{239+240}$Pu	2.86E-01		
			^{241}Am	6.96E-02		
	Building A-01, NLVF[d]	None	^{3}H	2.35E-03		
Stockpile Stewardship, Science, and Experimentation	BEEF[e]	None	DU	5.22E-02		
	DPFF[e]	None	^{3}H	6.57E+02		
			^{16}N	1.63E-04		
			^{19}O	2.11E-07		
			^{41}Ar	2.64E-07		
			Radionuclide	**Quantity (Ci/y)**	**Radionuclide**	**Quantity (Ci/y)**
	NCERC[e]	HEPA filter	^{3}H	3.13E-06	^{133}I	9.94E+00
			^{14}C	8.84E-06	^{135}I	3.04E+01
			^{16}N	1.27E+00	^{131m}Xe	4.02E-03
			^{19}O	2.25E-03	^{133}Xe	1.64E+00
			^{41}Ar	4.86E-01	^{133m}Xe	1.13E-01
			^{85}Br	7.95E+02	^{135}Xe	2.26E+01
			^{85}Kr	9.49E-05	^{135m}Xe	1.49E+02
			^{85m}Kr	9.12E+00	^{134}Cs	4.82E-08
			^{90}Sr	7.10E-04	^{137}Cs	7.36E-04
			^{95}Zr	1.32E-09	^{140}Ba	6.45E-01
			^{95}Nb	2.42E-09	^{140}La	4.90E-08
			^{95m}Nb	2.53E-10	^{141}Ce	2.35E-04
			^{99}Mo	2.91E-08	^{144}Ce	2.50E-05
			^{103}Ru	1.08E-09	^{144}Pr	5.88E-06
			^{106}Rh	1.22E-05	^{147}Nd	2.65E-09
			^{121m}Sn	3.17E-10	^{147}Pm	3.04E-11
			^{124}Sb	2.42E-06	^{149}Pm	6.27E-09
			^{125}Sb	8.67E-05	^{151}Pm	4.75E-09
			^{132}Te	1.89E+00	^{151}Sm	1.71E-05
			^{129}I	2.34E-10	^{153}Sm	1.02E-01
			^{131}I	5.47E-01	^{155}Eu	3.30E-05
					Radionuclide	**Quantity (Ci/y)**
Environmental Restoration and Waste Operations	E-Tunnel Ponds[f]	None	^{3}H	4.30E+00		
	UGTA Wells[f]	None	^{3}H	2.91E+00		
	Area 3 RWMS[b]	Soil cover over waste	^{3}H	4.51E+00		
	Area 5 RWMC[b]	Soil cover over waste	^{3}H	2.63E+00		
Mission Support	Building 23-652[g]	None	^{3}H	6.92E-07		

(a) All locations are on the NNSS except for Building A-01.
(b) Emission based on samples and CAP88-PC; see Appendix B.
(c) Emissions from soil re-suspension model; see Table C.1.
(d) Based on air concentrations and ventilation system; see Appendix D.
(e) Emission based on potential release reported by project personnel.
(f) Emission based on HTO discharged into containment pond(s) or onto the ground; see Appendix E.
(g) Based on concentrations used in Building 23-652 lab during 2017 - the most recent year an emission estimate is available.

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SECTION III
DOSE ASSESSMENTS

CRITICAL RECEPTOR AIR MONITORING

The NNSS demonstrates compliance with dose limits by reporting environmental measurements of radionuclide air concentrations near the NNSS borders and near the center of the NNSS. This critical receptor method [40 CFR 61.93 (5) and (g)] was accepted by EPA Region 9 for use on the NNSS in 2001 (EPA 2001a) and has been used to demonstrate compliance with the 40 CFR 61.92 dose standard since 2002. The six approved critical receptor locations are listed below and displayed in Figure 4 with NNSS emission locations and in Figure 5 along with the entire NNSS air sampling network.

- Area 6, Yucca
- Area 10, Gate 700 S
- Area 16, 3545 Substation
- Area 20, Schooner
- Area 23, Mercury Track
- Area 25, Gate 510

No changes to the critical receptor or routine air monitoring locations occurred during CY 2019 (Figure 5).

The six critical receptor locations can be thought of as worst case for an offsite receptor because these samplers are much closer to emissions sources. Table 6 displays the distances and direction between the critical receptor monitoring stations and offsite locations where members of the public potentially live, work, and/or go to school. The distance and direction between emission sources and the critical receptor sampling locations are listed in Table 7. The shortest distance between where a member of the public resides and a critical receptor monitoring station is 4 km. This is between the Gate 510 sampler, in the SW corner of the NNSS, and the northern edge of the community of Amargosa Valley. The shortest distance between an NNSS radionuclide emission source and a critical receptor monitoring station is 0.2 km. This is between Building 23-652 and the Mercury Track sampler. The Schooner sampler, in the NW corner of the NNSS, is listed as only 0.3 km from the center of the Schooner Crater but it is actually within the area physically affected by the nuclear test. Therefore, this station generally has the highest radionuclide concentrations of the six critical receptor stations. The distance from the Schooner sampler to the closest member of the public (Tolicha Peak) is 20 km, which is 100 times farther than it is from the emission source.

Compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) public air pathway dose limit of 10 mrem/y is demonstrated if the measured annual average concentration of each detected radionuclide at each of the six critical receptor locations is less than the NESHAP Concentration Level (CL) for Environmental Compliance (40 CFR 61, Appendix E, Table 2). The CL represents the annual average concentration of each radionuclide that would result in an EDE of 10 mrem/y (see Table 8). For multiple radionuclides, compliance with NESHAP is demonstrated when the sum of the fractions (determined by dividing each radionuclide's concentration by its CL and then adding the fractions together) is less than 1.0. The CY 2019 air sampling results for all manmade radionuclides detected from the six compliance stations are presented in Table 8. Concentration ratios for all NNSS air samplers are listed in Table 9. Presentation of air monitoring results in relation to the CL for non-critical receptor locations in Table 9 is provided as information only.

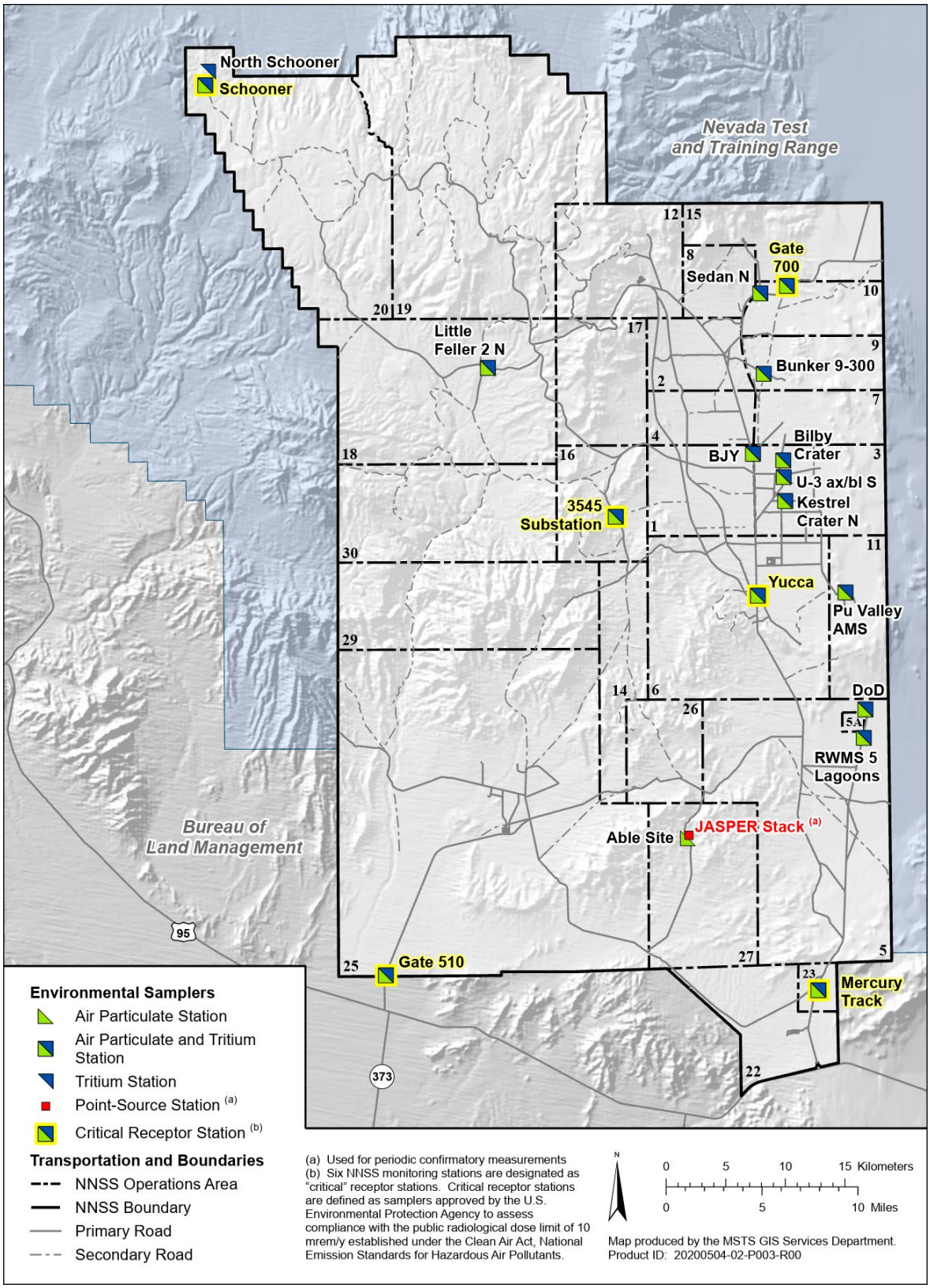

Figure 5. Air Sampling Network on the NNSS

Table 6. Distance and Direction from Critical Receptor Stations to Offsite Points of Interest

Critical Receptor Station	Distance[a] and Direction[b] to Nearest Offsite Locations		
	Offsite Residence	Offsite Business/ Office	Offsite School
Area 6, Yucca	47 km SW (Amargosa Valley)	38 km SSE (American Silica)	54 km SE (Indian Springs)
Area 10, Gate 700 S	49 km ENE (Medlin's Ranch)	56 km NNE (Rachel)	75 km SSE (Indian Springs)
Area 16, 3545 Substation	46 km SSW (Amargosa Valley)	46 km SSW (Amargosa Valley)	58 km SSW (Amargosa Valley)
Area 20, Schooner	36 km WSW (Sarcobatus Flat)	20 km WSW (Tolicha Peak)	56 km SSW (Beatty)
Area 23, Mercury Track	24 km SW (Crystal)	6.0 km SE (American Silica)	31 km SSW (Indian Springs)
Area 25, Gate 510	4 km S (Amargosa Valley)	3.5 km S (Amargosa Valley)	15 km SW (Amargosa Valley)

(a) Distance is shown in km. For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.

Table 7. Distance[a] and Direction[b] from Emission Sources to Critical Receptor Stations

Emission Source		Area 6, Yucca	Area 10, Gate 700 S	Area 16, 3545 Substation	Area 20, Schooner	Area 23, Mercury Track	Area 25, Gate 510
Legacy Contamination Sites, Grouped Area Sources	Area 1	11.7 SSE	17.0 NNE	8.2 WSW	52.5 NW	44.8 SSE	50.0 SSW
	Area 2	21.1 SSE	10.4 NE	14.7 SSW	46.1 WNW	54.4 SSE	57.7 SSW
	Area 3	9.6 SSW	16.6 N	14.2 WSW	58.8 NW	42.6 S	53.0 SW
	Area 4	16.2 SSE	12.8 NE	11.3 SW	49.7 WNW	49.6 SSE	54.1 SSW
	Area 5	20.5 NNW	44.1 N	33.1 NW	> 80 km	16.9 SSW	44.7 WSW
	Area 6	2.4 NE	28.1 N	13.3 NW	63.2 NW	32.0 SSE	42.1 SW
	Area 7	15.1 S	11.0 N	16.4 WSW	56.0 WNW	48.2 S	57.5 SW
	Area 8	26.5 S	5.7 E	21.5 SSW	46.1 WNW	60.0 S	64.5 SSW
	Area 9	19.3 S	7.0 NNE	17.7 SW	52.5 WNW	52.5 S	60.2 SSW
	Area 10[c]	24.5 S	2.6 NE	21.6 SW	50.2 WNW	57.7 S	64.5 SSW
	Area 11	8.6 WSW	24.5 NNW	20.7 WNW	68.1 NW	35.4 S	52.1 SW
	Area 12[c]	30.6 SSE	13.0 ESE	22.3 S	38.8 WNW	63.8 SSE	64.2 SSW
	Area 15	28.0 S	2.7 SE	24.8 SSW	49.3 WNW	61.3 S	67.8 SSW
	Area 16	15.2 ESE	24.0 NE	1.6 SE	48.4 NW	44.7 SSE	43.5 SSW
	Area 17	22.2 SE	17.5 ENE	11.3 S	41.6 NW	54.1 SSE	52.9 SSW
	Area 18	31.5 SE	29.1 ENE	18.1 SE	32.1 NW	59.9 SSE	50.5 S
	Area 19	42.4 SSE	27.4 ESE	31.0 SSE	24.3 WNW	74.2 SSE	67.8 S
	Area 20[c]	62.8 SE	51.3 ESE	49.7 SE	0.3 WNW	> 80 km	76.0 SSE
	Area 25	24.6 NE	45.9 NNE	22.2 NNE	62.5 NNW	31.7 SE	21.0 SSW
	Area 30	29.2 E	37.2 ENE	16.8 E	41.3 NNW	51.3 SE	37.4 S
Stockpile Stewardship, Science, and Experimentation	BEEF	16.5 SSE	12.1 NE	12.0 SW	49.9 WNW	49.9 S	54.8 SSW
	DPFF	7.4 W	27.3 N	20.7 WNW	69.3 NW	32.2 S	49.4 SW
	NCERC	6.4 N	32.5 N	17.8 NW	67.8 NW	27.1 S	40.4 SW
Environmental Restoration and Waste Operations	RNM-2S	16.5 NNW	41.0 N	28.8 NW	78.8 NW	18.6 S	42.3 WSW
	UE-5n	16.9 NNW	41.3 N	29.3 NW	79.3 NW	18.4 S	42.7 WSW
	ER-20-5-1	48.0 SE	40.8 E	34.6 SE	16.0 NNW	75.7 SE	61.2 S
	ER-20-5-3	48.0 SE	40.8 E	34.5 SE	16.0 NNW	75.7 SE	61.2 S
	U-20n PS 1DDh	45.8 SE	36.3 E	32.7 SE	17.3 NW	75.0 SSE	63.1 S
	UE-20n1	45.7 SE	36.2 E	32.7 SE	17.4 NW	75.0 SSE	63.2 S
	RWMS 3	10.1 SSW	16.1 N	14.4 WSW	58.6 NW	43.1 S	53.4 SW
	RWMC 5	13.3 NW	36.7 N	26.5 NW	76.3 NW	23.2 S	45.2 WSW
Mission Support	Building 23-652	33.6 N	59.2 N	43.3 NNW	> 80 km	0.2 WNW	36.5 W

(a) Distance is shown in km. For miles, multiply by 0.62.
(b) N=north, S=south, E=east, W=west in all direction combinations shown.
(c) Includes emissions from Sedan, E-Tunnel Ponds, and Schooner from Areas 10, 12, and 20, respectively.

Table 8. Average Radionuclide Concentrations at NNSS Critical Receptor Stations and Fraction of Concentration Level (CL) for CY 2019

Location	Radionuclide	Average Concentration in Air (pCi/m^3)[a]	CL[b] (pCi/m^3)	Average Concentration as Fraction of CL
Yucca	^{3}H	0.22×10^{0}	1500	0.0001
Gate 700 S		0.17×10^{0}		0.0001
3545 Substation		0.02×10^{0}		0.0000
Schooner		51.62×10^{0}		0.0344
Mercury Track		0.09×10^{0}		0.0001
Gate 510		0.09×10^{0}		0.0001
Yucca	^{137}Cs	-22.50×10^{-6}	0.019	0.0000
Gate 700 S		-26.59×10^{-6}		0.0000
3545 Substation		24.10×10^{-6}		0.0013
Schooner		85.53×10^{-6}		0.0045
Mercury Track		-87.32×10^{-6}		0.0000
Gate 510		-73.54×10^{-6}		0.0000
Yucca	^{241}Am	-1.67×10^{-6}	0.0019	0.0000
Gate 700 S		-0.36×10^{-6}		0.0000
3545 Substation		-0.84×10^{-6}		0.0000
Schooner		3.30×10^{-6}		0.0017
Mercury Track		-4.25×10^{-6}		0.0000
Gate 510		3.45×10^{-6}		0.0018
Yucca	^{238}Pu	1.73×10^{-6}	0.0021	0.0008
Gate 700 S		0.08×10^{-6}		0.0000
3545 Substation		0.57×10^{-6}		0.0003
Schooner		6.30×10^{-6}		0.0030
Mercury Track		0.26×10^{-6}		0.0001
Gate 510		1.49×10^{-6}		0.0007
Yucca	$^{239+240}Pu$	5.94×10^{-6}	0.0020	0.0030
Gate 700 S		17.24×10^{-6}		0.0086
3545 Substation		-1.42×10^{-6}		0.0000
Schooner		5.20×10^{-6}		0.0026
Mercury Track		2.80×10^{-6}		0.0014
Gate 510		-0.25×10^{-6}		0.0000
Yucca	Sum of Fractions by Locations	Sums for analytes listed above with negative values set to zero.		0.0039
Gate 700 S				0.0088
3545 Substation				0.0016
Schooner				0.0462
Mercury Track				0.0016
Gate 510				0.0026

(a) picocuries per cubic meter (pCi/m^3)
(b) Source: Table 2 in 40 CFR 61, Appendix E (Compliance Procedures Methods for Determining Compliance with Subpart I, 2019)

Table 9. Average Radionuclide Concentration Fraction of Concentration Level (CL) at all NNSS Air Stations, CY 2019

		Annual Average Concentration / Compliance Level					
Area	Sampling Station	^{3}H	^{137}Cs	^{238}Pu	$^{239+240}Pu$	^{241}Am	Sums of Fractions of CLs[a]
1	BJY	0.0002	0.0000	0.0008	0.0043	0.0000	0.0053
3	Bilby Crater	0.0002	0.0000	0.0001	0.0071	0.0000	0.0074
3	Kestrel Crater N	0.0002	0.0017	0.0003	0.0046	0.0000	0.0068
3	U-3ax/bl S	0.0003	0.0025	0.0000	0.0065	0.0003	0.0096
5	DoD	0.0005	0.0000	0.0004	0.0019	0.0021	0.0049
5	RWMS 5 Lagoons	0.0010	0.0001	0.0000	0.0028	0.0014	0.0053
6	Yucca[b]	0.0001	0.0000	0.0008	0.0030	0.0000	0.0039
9	Bunker 9-300	0.0002	0.0000	0.0002	0.0272	0.0023	0.0299
10	Gate 700 S[b]	0.0001	0.0000	0.0000	0.0086	0.0000	0.0087
10	Sedan N	0.0007	0.0000	0.0024	0.0235	0.0017	0.0283
11	Pu Valley AMS	0.0056	0.0000	0.0000	0.0265	0.0075	0.0396
16	3545 Substation[b]	0.0000	0.0013	0.0003	0.0000	0.0000	0.0016
18	Little Feller 2 N	0.0001	0.0020	0.0000	0.0017	0.0000	0.0038
20	North Schooner	0.0009	NM[c]	NM[c]	NM[c]	NM[c]	0.0009
20	Schooner[b]	0.0344	0.0045	0.0030	0.0026	0.0017	0.0462
23	Mercury Track[b]	0.0001	0.0000	0.0001	0.0014	0.0000	0.0016
25	Gate 510[b]	0.0001	0.0000	0.0007	0.0000	0.0018	0.0026
27	Able Site	NM[c]	0.0000	0.0006	0.0009	0.0006	0.0021

(a) Negative values set to zero before summing.
(b) Critical Receptor sample location.
(c) NM = not measured. Only air particulates or atmospheric moisture are sampled at certain locations.

CAP88-PC DOSE ASSESSMENT

The radioactive air emissions from each NNSS source listed in Table 5 were modeled using the Clean Air Package, 1988 model (CAP88-PC, Version 4.0; EPA 2014). Emission locations for Legacy Contamination Sites, Grouped Area Sources, were either the center of the most contaminated location within each of the NNSS operational areas, or the center-point of the operational area if the surface contamination was relatively uniform. Emission locations from operation or projects locations were the known release points. Tritium emissions from the E-Tunnel Ponds were included in the Area 12 emission. Wind files containing frequency distributions of wind speed, direction, and stability class from CY 2019 meteorological stations on the NNSS were provided by the National Oceanic and Atmospheric Administration, Air Resources Laboratory, Special Operations and Research Division (ARL/SORD) (Appendix F). CAP88-PC-predicted annual doses (mrem/y) from each emission source to each receptor location are listed in Table 10.

COMPLIANCE ASSESSMENT

As can be seen in Table 8, the annual average concentrations of detected radionuclides and their fraction of the NESHAP compliance level for each of the six NNSS critical receptor stations are all below 5% of the CLs with the ^{3}H average at the Schooner sampler station being the maximum at about 3.4% of the CL. The average concentration of ^{3}H is high at Schooner because the air sampler is so close to the Area 20 emission source (Table 7). The highest sum of the fractions at critical receptors stations (0.046) was measured at the Schooner sampler. This is well below 1.0 and therefore in compliance with the NESHAP standard. The last column of Table 10 lists the total CAP88-PC calculated dose to offsite receptors from all NNSS emissions. The highest predicted dose is at the Cinder Cone Pit Mine but nobody is known to reside there full-time. The maximally exposed individual (MEI) is predicted to be a person residing in Amargosa Valley or at the NTTR and receive an effective dose equivalent of 0.057 mrem/y. For comparison, the fractions of the 10 mrem/y air pathway dose limit from CAP-88 modeled MEI dose estimates from CY 1992 to CY 2004 and CY 2017 to CY 2019 are displayed in Figure 6 along with the highest critical receptor station monitoring results (Schooner) from CY 2005 to CY 2019.

Based on the CAP88-PC modeling, the only radionuclides contributing more than 10% to the MEI dose were ^{239}Pu (70.9%) and ^{241}Am (14.8%). ^{238}Pu accounted for 6.3% and tritium accounted for 4.5%. No other radionuclide exceeded 1% of the dose.

Table 10. CAP88-PC Dose (mrem/y) from NNSS Sources (" - " indicates receptor is > 80 km [50 mi] from emission)

Location	Grouped Area Sources (a)	BEEF	DPFF	NCERC	UGTA Wells	RWMS 3	RWMC 5	Building 23-652	Total From All NNSS Sources (mrem/y)
Cinder Cone Pit	8.9E-02	4.4E-04	2.5E-03	5.2E-04	1.9E-05	2.0E-05	2.2E-05	3.5E-11	9.2E-02
Amargosa Valley (center)	5.3E-02	5.1E-04	2.5E-03	6.9E-04	1.8E-05	2.0E-05	2.2E-05	3.7E-11	5.7E-02
NTTR	5.3E-02	2.8E-04	2.5E-03	1.2E-03	1.9E-05	2.2E-05	2.2E-05	3.4E-11	5.7E-02
Amargosa Valley (N. end)	5.2E-02	8.3E-04	2.5E-03	1.1E-03	1.9E-05	2.0E-05	2.2E-05	3.6E-11	5.6E-02
U.S. Ecology	4.7E-02	1.4E-04	2.4E-03	3.5E-04	1.9E-05	2.0E-05	2.2E-05	3.4E-11	5.0E-02
Crystal	4.0E-02	1.5E-03	2.6E-03	1.6E-03	3.3E-07	2.1E-05	2.3E-05	4.5E-11	4.5E-02
Cedar Pipeline Ranch	3.6E-02	3.2E-04	-	-	1.9E-05	2.0E-05	-	-	3.7E-02
Cactus Springs	2.9E-02	6.6E-04	2.8E-03	2.1E-03	3.4E-07	2.2E-05	2.4E-05	3.4E-11	3.5E-02
Beatty	3.1E-02	1.4E-04	2.4E-03	2.4E-04	1.8E-05	2.0E-05	2.1E-05	1.0E-09	3.4E-02
Springdale	3.0E-02	1.6E-04	2.4E-03	2.0E-04	1.9E-05	2.0E-05	3.5E-05	1.0E-09	3.2E-02
Penoyer Farm	2.7E-02	2.6E-04	2.4E-03	-	1.9E-05	2.0E-05	-	-	3.0E-02
Johnnie	2.3E-02	1.3E-03	2.7E-03	2.0E-03	3.3E-07	2.1E-05	2.3E-05	3.9E-11	2.9E-02
Indian Springs	2.2E-02	2.0E-04	2.7E-03	1.8E-03	3.3E-07	2.2E-05	2.3E-05	3.4E-11	2.7E-02
Rachel	2.4E-02	2.5E-04	-	-	1.8E-05	2.0E-05	-	-	2.4E-02
Medlin's Ranch	2.0E-02	1.4E-04	2.5E-03	3.8E-04	4.4E-07	2.1E-05	2.1E-05	-	2.3E-02
Tolicha Peak	2.1E-02	1.9E-04	-	2.7E-04	1.8E-05	2.0E-05	-	-	2.1E-02
Tempiute	1.5E-02	2.3E-04	-	-	-	2.0E-05	-	-	1.5E-02
Southern Desert Correctional Center	9.5E-03	-	2.7E-03	1.2E-03	3.2E-07	2.2E-05	2.3E-05	3.4E-11	1.3E-02
Sarcobatus Flat	1.1E-02	1.1E-04	-	-	1.8E-05	-	-	-	1.1E-02
Cold Creek	6.8E-03	-	2.7E-03	1.6E-03	3.3E-07	2.1E-05	2.3E-05	3.4E-11	1.1E-02
Lee Canyon Residences (center point)	2.1E-03	-	2.6E-03	1.2E-03	3.2E-07	-	2.3E-05	3.4E-11	5.9E-03
Ash Meadows	2.2E-03	-	2.5E-03	9.0E-04	3.2E-07	2.1E-05	2.2E-05	3.9E-11	5.7E-03
Scotty's Junction	3.2E-03	-	-	-	1.8E-05	-	-	-	3.2E-03
Corn Creek Station	7.9E-05	-	2.7E-03	-	3.1E-07	-	2.2E-05	3.3E-11	2.8E-03
Alamo	1.6E-03	-	-	-	-	-	-	-	1.6E-03
Tonapah Test Range	1.5E-03	-	-	-	1.8E-05	-	-	-	1.6E-03
Death Valley Junction	7.5E-04	-	-	6.9E-04	3.1E-07	-	3.5E-05	3.8E-11	1.5E-03
Mt. Charleston	1.1E-04	-	-	1.2E-03	3.2E-07	-	2.3E-05	3.4E-11	1.3E-03
Pahrump	1.5E-04	-	-	1.0E-03	3.2E-07	-	2.3E-05	3.5E-11	1.2E-03
Furnace Creek	6.4E-04	-	-	-	-	-	-	1.0E-09	6.4E-04
Reeds Ranch	5.7E-04	-	-	-	-	-	-	-	5.7E-04
Ash Spring	5.3E-04	-	-	-	-	-	-	-	5.3E-04
Lida Junction	4.2E-04	-	-	-	1.8E-05	-	-	-	4.4E-04
Gold Point	3.8E-04	-	-	-	-	-	-	-	3.8E-04
Goldfield	3.4E-04	-	-	-	-	-	-	-	3.4E-04
Gemfield	3.3E-04	-	-	-	-	-	-	-	3.3E-04
Kyle Canyon Rd Residences (mid-point)	7.5E-05	-	-	-	4.5E-07	-	3.5E-05	1.0E-09	1.1E-04
Las Vegas	6.9E-05	-	-	-	-	-	-	1.0E-09	6.9E-05

(a) Tritium from Sedan, E-Tunnel Ponds, and Schooner are included in the Grouped Area Sources for Areas 10, 12, and 20, respectively.

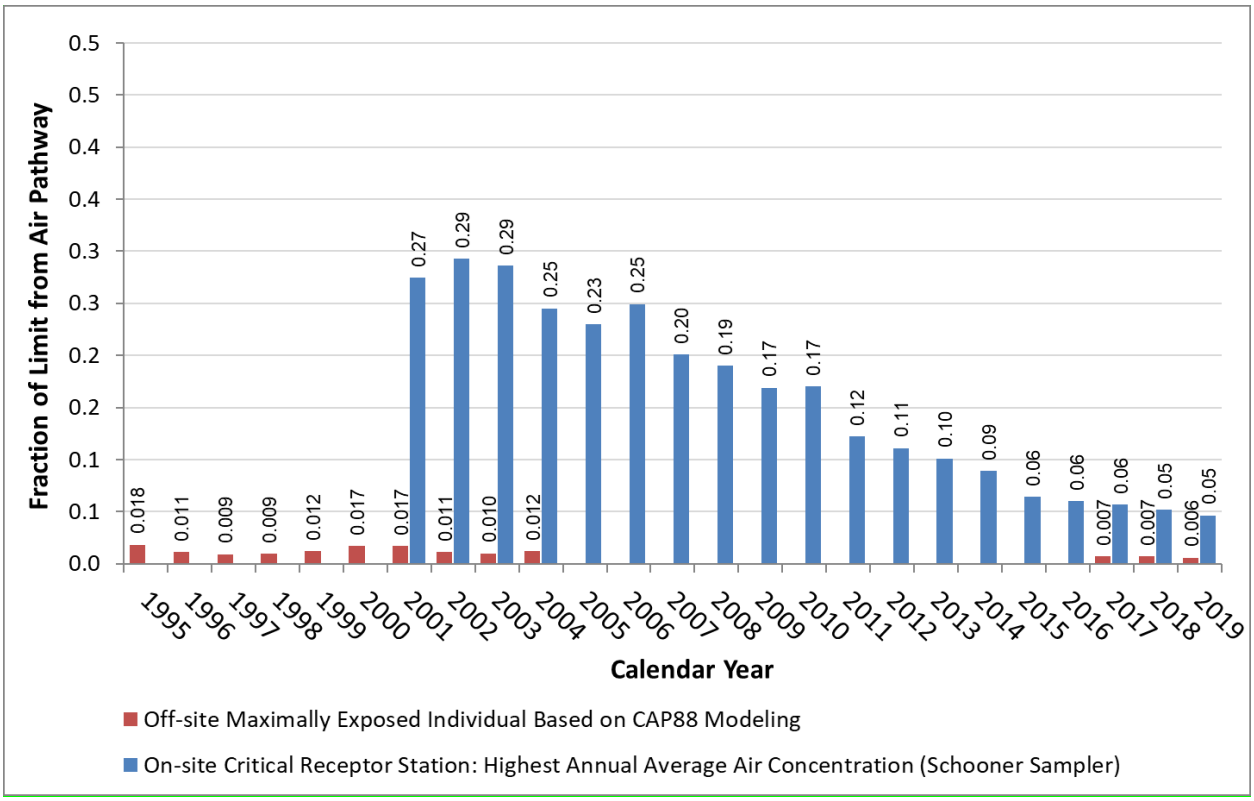

Figure 6. Fraction of the 10 mrem/y Air Pathway Dose Limit for CAP88-PC Modeled MEI Dose and Highest Critical Receptor Station Monitoring Results

SECTION IV
ADDITIONAL INFORMATION

NEW CONSTRUCTION/MODIFICATION ACTIVITIES

No new construction or modification activities were evaluated during CY 2019.

PERIODIC CONFIRMATORY MEASUREMENTS

NESHAP regulations require periodic confirmatory measurements for release sources that result in less than 1% of the standard to verify low emissions [40 CFR 61.93 (4)(i) and (e)]. The Memorandum of Understanding between the EPA and DOE states that "engineering calculations and/or representative measurements may be used to comply with periodic confirmatory measurement requirements" (EPA and DOE 1995). This section lists the periodic confirmatory measurements that were conducted for CY 2019 emission sources.

Joint Actinide Shock Physics Experimental Research (JASPER)

A sample of stack effluents was taken, July 10–11, 2019, during a test using special nuclear material. It was analyzed for ^{238}Pu, $^{239+240}$Pu, and ^{241}Am. No radionuclides were detected in the sample. There is no evidence of radionuclide emissions from JASPER operations, which confirms the assessment of this potential source having emission less than 1% of the standard (National Security Technologies, LLC, 2013a).

North Las Vegas Facility (NLVF), Building A-01

Biannual measurements of ^{3}H concentrations in air in Building A-01 are made as a best management practice. The potential dose from Building A-01 emissions is calculated each year based on this monitoring information. The emissions during CY 2019 were analogous to the past few years and the resultant dose (0.000012 mrem/y) was well below the 0.1 mrem/y level specified in 40 CFR 61.96. A summary of this is presented in Appendix D.

Big Explosives Experiment Facility (BEEF)

Facility management personnel reported the maximum amount of radioactive material that could be used at the facility. All of this amount (Table 5) was conservatively modeled as an emission using CAP88-PC software. The resultant potential effective dose equivalent to the maximally exposed individual was determined to be 0.0015 mrem/y (Table A-1). This confirms this location continues to have emissions less than 1% of the standard.

Dense Plasma Focus Facility (DPFF)

Project personnel reported the amount of tritium used at the facility (Table 5). This amount was modeled as an emission using CAP88-PC software. The resultant potential effective dose equivalent to the maximally exposed individual was determined to be 0.0028 mrem/y (Table A-1). This confirms this location continues to have emissions less than 1% of the standard.

National Criticality Experiments Research Center (NCERC)

Project personnel provide the number of fissions produced by the assembly machines during CY 2019. The total number of fissions (6.01E+17) were multiplied by the maximum of either the thermal or fast fission yield for uranium-235 (Nichols et al. 2008) to obtain a conservative estimate of fission products produced. The potential emission was obtained by multiplying the 40 CFR 61 Appendix D emission factor by the total activity. While the temperature from most bursts will be less than 100ºC, a temperature of 850 ºC has been reached in previous research so this temperature (850 ºC) was considered the operating temperature for this emission calculation. The method for evaluation of the physical state of the fission products was based on the *Federal Facility Compliance Agreement* (1996) between the U.S. EPA Region 6 and the U.S. Department of Energy, Los Alamos Site Office which states: "A radionuclide material that has a boiling point greater than 2000 ºC and is heated to within 1000 ºC of its boiling point or higher, or is intentionally dispersed into the environment, must be considered a gas. If the material is not heated to within 1000 ºC of its boiling point, the material would be considered a solid or a liquid depending on its actual physical state at that temperature." The 40 CFR 61 Appendix D rule (all material greater than 100 ºC will be considered a gas) was applied to all radionuclides with a boiling point less than or equal to 2000 ºC. This conservative potential emission (Table 5) was modeled using CAP88-PC software and the resultant potential effective dose equivalent to the maximally exposed individual was determined to be 0.0021 mrem/y (Table A-1). This confirms this location continues to have emissions less than 1% of the standard.

Other Emission Sources

The basis for estimate of CY 2019 radionuclide emissions (Table 5) other than those listed above can be found in Appendices B, C, and E. The potential dose to the maximally exposed individual from those emissions are listed in Table A-1. All are much less than 0.1 mrem/y, confirming these locations and activities continue to have emissions less than 1% of the standard.

UNPLANNED RELEASES

There were no known unplanned radionuclide releases during CY 2019.

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APPENDICES

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Appendix A

Radionuclide Air Emission Sources

Table A.1. Facilities or Areas from Which Radionuclides Were Released to Air in Calendar Year (CY) 2019

Emission Source	Emission Type	Radionuclide(s) Emitted	Handling/ Processing	Nature of Emissions	Effluent Controls	MEI Dose[(a)] (Location)	Distance[(b)] and Direction[(c)] to Nearest Air Sampler(s)
Legacy Contamination Sites							
Sedan Crater (Plowshare), Area 10	Diffuse	Tritium (^{3}H) as tritiated water (HTO), americium (Am), plutonium (Pu), activation and fission products	None	^{3}H as HTO evaporation from soil or transpiration from plants and suspension of contaminated soil by wind	None	0.012 (N. end of Amargosa Valley)	• Sedan N: 0.8 kilometers (km) N • Critical receptor sampler (Gate 700 S): 2.6 km NE
Schooner Crater (Plowshare), Area 20	Diffuse	^{3}H as HTO, Am, Pu, activation and fission products	None	^{3}H as HTO evaporation from soil or transpiration from plants and suspension of contaminated soil by wind	None	0.0082 (Tolicha Peak)	• Critical receptor sampler (Schooner): 0.3 km WNW
Grouped Area Sources – All Nevada National Security Site (NNSS) Areas	Diffuse	Am, Pu, activation and fission products (^{3}H as HTO as well, but the vast majority are emitted from Sedan and Schooner—see above)	None	Wind causing suspension of soil containing small amounts of historical fallout/legacy radioactive materials	None	0.053[(d)] (center of Amargosa Valley)	• See Figure 4 and Table 7
NLVF, Building A-01	Point (vent on side of building)	Parts of the basement were contaminated with ^{3}H in 1995 including a vacant radiation source well	Air flow through building ventilation system	^{3}H as HTO through emanation from building materials into the air and exhausted from the building through the ventilation system	None	0.000012 (100 m NW of Building A-1)	• Biannual sampling inside room that was contaminated

(a) mrem/y.
(b) Distance is shown in km. For miles, multiply by 0.62.
(c) N=north, S=south, E=east, W=west in all direction combinations shown.
(d) Includes dose from Sedan and Schooner Craters listed above.

Table A.1. Facilities or Areas from Which Radionuclides Were Released to Air in Calendar Year (CY) 2019 (continued)

Facility or Area	Emission Type	Radionuclide(s) Emitted	Handling/ Processing	Nature of Emissions	Effluent Controls	MEI Dose[a] (Location)	Distance[b] and Direction[c] to Nearest Air Sampler(s)
Stockpile Stewardship, Science, and Experimentation							
Big Explosives Experiment Facility, Area 4	Diffuse	Depleted uranium	Fuel fire experiment	DU released during experiment	None	0.0015 (Crystal)	• Bunker 9-300: 5.5 km ENE • Critical receptor sampler (3545 Substation) 12.0 km SW
Dense Plasma Focus, Area 11	Point (stack)	^{3}H, short-lived activation products in air	Production of neutrons using a deuterium-^{3}H reaction	^{3}H gas released through a stack exhaust	None	0.0028 (Cactus Springs)	• Pu Valley AMS: 1.2 km N • Critical receptor sampler (Yucca) 7.4 km W
National Criticality Experiments Research Center, Area 6	Point (stack)	Various activation and fission products (see Table 5)	Critical mass assembly machines at very low power	Activation and fission products in gas form	Exhaust goes through HEPA filtration	0.0021 (Cactus Springs)	• Critical receptor sampler (Yucca): 6.4 km N

(a) mrem/y.
(b) Distance is shown in km. For miles, multiply by 0.62.
(c) N=north, S=south, E=east, W=west in all direction combinations shown.

Table A.1. Facilities or Areas from Which Radionuclides Were Released to Air in Calendar Year (CY) 2019 (continued)

Facility or Area	Emission Type	Radionuclide(s) Emitted	Handling/ Processing	Nature of Emissions	Effluent Controls	MEI Dose[a] (Location)	Distance[b] and Direction[c] to Nearest Air Sampler(s)
Environmental Restoration and Waste Operations							
E-Tunnel Ponds, Area 12	Diffuse	^{3}H in groundwater flowing from fissures in historical nuclear tests tunnel system	Controlled drainage and containment of groundwater from the tunnel in a series of earthen ponds	^{3}H as HTO through evaporation or transpiration from plants	None	0.000018 (NTTR)	• Little Feller 2N: 11.9 km WSW • Critical receptor sampler (Gate 700 S): 15 km E
Underground Test Area Activity wells	Diffuse	^{3}H as HTO	Groundwater pumped to the surface	Evaporation of ^{3}H as HTO	None	0.000019 (U.S. Ecology)	• Critical receptor sampler (Schooner):16.5 km NW
Area 3 Radioactive Waste Management Site (RWMS)	Diffuse	^{3}H as HTO (only radionuclide attributable to the low-level waste [LLW])	Subsurface burial of waste	^{3}H as HTO through evaporation from soil or transpiration from plants	Soil cover	0.000022 (Cactus Springs)	• U-3ax/bl S: < 0.3 km in multiple directions; near the center of the Area 3 RWMS • Critical receptor sampler (Yucca): 10 km SSW
Area 5 Radioactive Waste Management Complex (RWMC)	Diffuse	^{3}H as HTO (only radionuclide attributable to LLW, mixed LLW)	Subsurface burial of waste	^{3}H as HTO through evaporation from soil or transpiration from plants	Soil cover	0.000035 (Kyle Canyon Rd)	• DoD: 0.4 km from NE edge of the Area 5 RWMC • Critical receptor sampler (Yucca): 14 km to the NNW
Mission Support							
Environmental Monitoring Building 23-652, Area 23	Point (stack)	^{3}H as HTO	Distillation or drying	^{3}H emission during distillation of samples and preparation of standards	None	0.000000001 (Kyle Canyon Rd)	• Critical receptor sampler (Mercury Track): 0.2 km to the east-southeast

(a) mrem/y.
(b) Distance is shown in km. For miles, multiply by 0.62.
(c) N=north, S=south, E=east, W=west in all direction combinations shown.

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Appendix B

NNSS Tritium Emissions Estimated from Air Sampling Data

BACKGROUND INFORMATION

Diffuse emissions of tritiated water (HTO) from the Nevada National Security Site (NNSS) include evaporation from containment ponds, evapotranspiration of soil moisture diffusing through waste covers at the Area 3 Radioactive Waste Management Site (RWMS), the Area 5 Radioactive Waste Management Complex (RWMC), and evapotranspiration of HTO from soil contaminated by atmospheric or near-surface past nuclear weapon testing. Locations that make up the majority of diffuse tritium (^{3}H) emissions on the NNSS are the Schooner and Sedan nuclear test areas, the Area 3 RWMS, the Area 5 RWMC, and the containment ponds at E-Tunnel. Emissions from the E-Tunnel ponds were not estimated from air sampling data because the total volume of water and ^{3}H concentration of the water was known, allowing for an estimate described in Appendix E. For the remaining sites listed, emissions were estimated by scaling concentrations of ^{3}H in air predicted by a modeled 1 curie (Ci) release to concentrations measured at nearby sampling stations. Figure 5 of this report shows the current NNSS air sampling station locations, and Table B.1 lists the samplers near the major diffuse ^{3}H emission locations.

SOURCE TERM ESTIMATES

For each ^{3}H emission location, the Clean Air Package 1988 (CAP88-PC) model was used to estimate the ^{3}H concentration that would be expected at nearby air samplers if 1 Ci of ^{3}H were released from the center of the source location. The total annual emission from each source was then calculated by dividing the annual average concentration of ^{3}H measured at each sampling location adjacent to the source by the CAP88-PC-predicted annual average concentration for a 1 Ci release at each of the same sampling locations. Table B.1 lists the estimated emissions for each source location.

Table B.1. Tritium Emissions from Airborne Tritium Sampling Results during CY 2019

Emission Source	Air Sampler	Annual Average Tritium Concentration (pCi/m^3)[(a)]	CAP88-PC Concentration for 1 Ci Emission (pCi/m^3)	Predicted Tritium Emission (Ci)	Emission Source Average (Ci)[(a)]
Area 3 RWMS	Bilby Crater	0.29	0.049	5.92	4.5
	Kestrel Crater N	0.31	0.10	3.10	
Area 5 RWMC	DOD	0.70	0.253	2.77	2.6
	RWMS 5 Lagoons	1.53	0.613	2.50	
Area 10, Sedan	Gate 700 S [(b)]	0.17	0.014	12.14	9.8
	Sedan N	1.01	0.137	9.37	
Area 20, Schooner	North Schooner	1.34	0.174	7.70	7.7

(a) Average of emissions predicted by samplers for an emission source.
(b) Critical Receptor Station.

Appendix C

Emissions of Radionuclides from Diffuse Legacy Sites Based on Historical Soil Survey Data and Soil Re-suspension Model

BACKGROUND INFORMATION

Operations Areas 1 through 12 and 15 through 30 on the Nevada National Security Site (NNSS) contain diffuse sources of radionuclides. Historical soil surveys have identified the location of these sources on the NNSS and provided estimates of the amounts of radionuclides that remain in the surface soils (U.S. Department of Energy [DOE] 1991; see Table 1 of this report). The soil, and associated radionuclides, may become airborne due to wind. Results from air samples from these areas indicate that only americium-241 (^{241}Am) and plutonium-239+240 ($^{239+240}$Pu) are routinely detected, and those are in concentrations only slightly above the minimum detectable concentrations. The total emissions (in curies [Ci]) produced each year from all known manmade radionuclides in soil at legacy sites on the NNSS are estimated with a mathematical re-suspension model. This appendix describes all the calculations involved in producing the emission estimates.

RE-SUSPENSION CALCULATIONS

These calculations are needed to estimate how much of the radionuclides in surface soils could actually become airborne (re-suspended) and therefore become an emission. A conservative estimate of emissions from diffuse sources is obtained by the use of a re-suspension equation with parameters derived from actual studies at the NNSS. In NUREG/CR-3332 (U.S. Nuclear Regulatory Commission 1983), pages 5-30, an equation for calculating a suspension rate (fraction re-suspended per second [s]) is given as follows:

$$S = K \times V_g$$

where: S = fractional re-suspension rate (per s), or the fraction of the inventory re-suspended per s
K = re-suspension factor (per meter [m])
V_g = deposition velocity (meters per second [m/s])

The values of K and V_g used in this re-suspension equation are taken from DOE (1992), with values of K provided on page 75. An average of the values is 2×10^{-10}/m. Ranges in V_g of 0.01 to 0.05 m/s, presented in DOE (1992), are used as conservative estimates. When these values are used in the above equation, S is between 2×10^{-12} and 1×10^{-11} per s. To be conservative, the higher fractional re-suspension rate of 1×10^{-11}/s is used. For example, the emission rate in picocuries (pCi)/s for $^{239+240}$Pu from Area 3 is calculated from the product of the $^{239+240}$Pu inventory (37 Ci from Table 1) and S as shown below. The estimated total annual emission is expressed in millicuries per year (mCi/y).

$$37\ Ci \times \frac{10^{-11}}{s} \times \frac{3600\ s}{hour} \times \frac{24\ hours}{day} \times \frac{365\ days}{yr} = \frac{1.17 \times 10^{-2} Ci}{yr}\ or\ \frac{11.7\ mCi}{yr}$$

This method was used for calculating the emissions of manmade radionuclides from all other areas. The results are shown in Table C.1.

Table C.1. Emission Estimates from Inventories[(a)] of Manmade Radionuclides in NNSS Surface Soil

	Annual Emission (mCi) Using Emission Factor of 1 x 10^{-11} s^{-1}								
Area	**^{60}Co**	**^{90}Sr**	**^{137}Cs**	**^{152}Eu**	**^{154}Eu**	**^{155}Eu**	**^{238}Pu**	**$^{239+240}$Pu**	**^{241}Am**
1	0.0072	2.3	1.4	1	0.0029	0.0021	1.6	7.6	1.9
2	0.0078	7.1	3.8	0.97	0.00	0.0017	2.1	6.9	1.5
3	0.0065	5.1	1.9	1.3	0.0029	0.0021	0.77	12	2.4
4	0.01	2	1.9	0.63	0.00	0.00086	3.2	13	3.1
5	0.0039	0.14	0.064	0.7	0.0058	0.00	0.025	1.5	0.31
6	0.0013	0.54	0.45	0.00	0.00	0.00	0.82	2.6	0.74
7	0.0065	1.4	0.83	1.5	0.0058	0.0013	0.15	5	1.1
8	0.037	3.9	6.7	0.31	0.00	0.0026	2	35	8.1
9	0.0046	2	1.4	1.6	0.0058	0.0013	0.55	28	3.7
10	0.063	8.5	13	0.15	0.0087	0.021	4.7	35	8.7
11	0.00	0.046	0.08	0.00	0.00	0.00	0.12	9.1	1.8
12	0.0078	2.6	3.2	0.00	0.00	0.00	2.1	12	2.8
15	0.002	3.4	3	0.00	0.00	0.00	1.9	20	4.1
16	0.00065	0.57	0.46	0.00	0.00	0.00	0.37	1.2	0.31
17	0.0065	2.9	2.4	0.00	0.00	0.00	1.1	5.7	1.3
18	0.0046	2.6	1.6	0.077	0.0029	0.0034	1.4	32	8.4
19	0.0072	4.8	5.8	0.00	0.00	0.00	8	44	10
20	0.051	0.67	0.88	0.9	0.047	0.021	7.5	13	8
25	0.00	0.015	0.032	0.028	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.0052	0.2	0.24	0.049	0.0029	0.00086	1.1	4.4	1.3
Total (mCi/y)	**0.23**	**51**	**50**	**9.2**	**0.085**	**0.058**	**40**	**290**	**70**

(a) Radioactive inventories from Table 5 in DOE/NV/10845--02 (DOE 1991) and decay corrected to the middle of CY 2019 (July 2, 2019), with inclusion of ingrowth of ^{241}Am from ^{241}Pu.

As shown in Table C.1, the estimated total emissions from soil inventory data and from the re-suspension model are reported to two significant figures (mCi/y). These are shown in Tables 3 and 5 of this report (as Ci/y), which summarizes all measured or computed emissions from the NNSS in calendar year 2019. The spatial relation between these diffuse emission locations and the critical receptor stations can be seen in Figure 4.

Appendix D

Potential Radionuclide Emissions and Dose from the North Las Vegas Facility

As discussed in the 1995 National Emission Standard for Hazardous Air Pollutants (NESHAP) report (U.S. Department of Energy 1996), a container of tritium-aluminum foils was opened in Building A-01 at the North Las Vegas Facility (NLVF) and emitted at least 1 curie (Ci) of tritium into a basement area used as a fixed radiation source range. Environmental surveillance began on the day notification of the tritium leak occurred. Environmental tritiated water (HTO) samplers were installed at three locations outside the facility. Later, an HTO sampler was installed in the basement and operated continuously so that progress on cleanup of the spill could be monitored. After cleanup, the environmental samplers were removed, but the basement air sampler continued operation through January 5, 1998, at which time samples were collected one to four times annually. From 1995 to the present, results and the effective dose equivalent (EDE) to the maximally exposed individual (MEI) offsite at the perimeter fence have been reported in the annual NESHAP reports.

During the years 1999 through 2019, air sampling for HTO in the basement was conducted intermittently. For CY 2019, the results of two atmospheric moisture samples were 234 picocuries per cubic meter (pCi/m^3) for the sample collected April 9–16, 2019, and 237 pCi/m^3 for the sample collected September 3–10, 2019. The average of these sample results (235 pCi/m^3) was multiplied by the room ventilation rate (673 cubic feet per minute [ft^3/min]) to determine the total annual emission rate as shown below. The estimated total annual emission is expressed in millicuries per year (mCi/y).

$$\frac{235\ pCi}{m^3} \times \frac{673\ ft^3}{min} \times \frac{0.02832\ m^3}{ft^3} \times \frac{525{,}600\ min}{y} \times \frac{1\ \times 10^{-9}\ mCi}{pCi} = \frac{2.35\ mCi}{y}$$

A dose coefficient of 5.0×10^{-6} millirem per year per millicurie (mrem/y/mCi) released is used to determine dose to the MEI from NLVF tritium emissions. This is based on earlier results from the Clean Air Package 1988 model using conservative assumptions to maximize dose and observed tritium emissions. This coefficient multiplied by the tritium emission for CY 2019 gave the estimated EDE to the nearest member of the public outside the perimeter fence shown below in both mrem/y and microrem per year (µrem/y).

$$\frac{2.35\ mCi}{y} \times \frac{5.0\ \times 10^{-6} mrem}{mCi} = \frac{0.000012\ mrem}{y}\ or\ \frac{0.012\ \mu rem}{y}$$

A comparison of the emission rates and radiation dose to the MEI since 2005 is presented in Table D.1.

Table D.1. Comparison of Tritium Emission Rates from Building A-01, NLVF from 2005 to 2019

Year	Tritium Emission Rate (mCi/y)	EDE to MEI (µrem/y)
2005	20	0.10
2006	13.2	0.07
2007	12.3	0.06
2008	11.1	0.06
2009	8.7	0.044
2010	6.45	0.032
2011	4.83	0.024
2012	4.74	0.024
2013	2.27	0.011
2014	1.72	0.0086
2015	2.39	0.012
2016	2.14	0.011
2017	1.95	0.0098
2018	1.59	0.008
2019	2.35	0.012

Appendix E

Calculation of Tritium Emissions from Contaminated Groundwater Discharges

The calendar year (CY) 2019 air emissions (in curies [Ci]) of tritium, as tritiated water from contaminated groundwater sources, were conservatively estimated. Emissions were computed as the product of the volume of water (in liters [L]) either pumped or naturally emerging to the surface and the tritium concentration (as picocuries per liter [pCi/L]) measured in that water using the following formula. It was assumed that all of the tritiated water evaporated.

$$Water\ Concentration\ \left(\frac{pCi}{L}\right)\ x\ Water\ Volume\ (L)\ x\ \frac{1\ x\ 10^{-12}\ Ci}{pCi}$$

Water flow-rate from the E-Tunnel is measured monthly and the tritium concentration in the water is measured annually in support of Water Pollution Control Permit NEV 96021. The total volume of water is determined by multiplying the flow-rate by the number of days in the month when the measurement was taken, then summed for all 12 months. Because the tritium concentration is decreasing over time, the value used to determine the emission was the average of the CY 2018 and CY 2019 samples (one sample collected in October, 2018 and one sample collected in September, 2019).

The volume of contaminated water pumped from wells is measured throughout the purging and sampling process. Samples are collected for analysis of tritium throughout the time during which water is pumped from the wells. The tritium concentration used to determine the emission is an average representative of all water pumped to the surface.

The tritium concentration and volume of groundwater discharges during 2019 are listed in Table E.1. The volume of water multiplied by the tritium concentration yields the estimated tritium emission to air during 2019 under the assumption that all of the water evaporated during 2019.

Table E.1. Tritium Concentrations, Water Volumes, and Estimated 2019 Tritium Emissions from Contaminated Groundwater Brought to the Surface

Location	Tritium Concentration (pCi/L)	Water Volume (L) [(a)]	Tritium Emission (Ci)
E-Tunnel Ponds	272,500 [(b)]	15,781,248	4.30
Well UE-5n	120,000	124,801	0.015
Well RNM-2S	71,700	280,393	0.020
Well U-20n PS 1DDh	13,100,000	44,509	0.58
Well UE-20n1	32,600,000	43,510	1.42
Well ER-20-5-1	20,000,000	43,082	0.86
Well ER-20-5-3	67,000	52,413	0.0035

(a) All water was assumed to evaporate during CY 2019.
(b) Average of results from October 2018 and September 2019 samples.

Appendix F

Identification and Justification for the Development of Meteorological Data Used as Input to Clean Air Package 1988 (CAP88-PC)

Meteorological support, observations, and climatological services for the Nevada National Security Site (NNSS) are provided to the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO) by the Air Resources Laboratory, Special Operations and Research Division (ARL/SORD). The ARL/SORD is a National Oceanic and Atmospheric Administration (NOAA) office and supports NNSA/NFO programs under the authority of an Interagency Agreement between NOAA and NNSA/NFO.

METEOROLOGICAL OBSERVATIONS

The ARL/SORD manages, operates, and maintains a meteorological monitoring program that is designed and used to support the NNSA/NFO-authorized activities on the NNSS. This vital program consists of many meteorological monitoring systems that have been brought together under the Meteorological Integrated Data Network (MIDNET). The MIDNET includes a Meteorological Data Acquisition (MEDA) network of 23 meteorological towers located on the NNSS (Figure F.1) and one on Yucca Mountain. The MIDNET consists of communications systems, local area networks, and surface-based instrumentation used to measure wind direction and speed, temperature, relative humidity, atmospheric pressure, and precipitation. The MIDNET has been operated on the NNSS for more than 40 years, has undergone several modernizations and upgrades, and serves as a solid basis for deriving climatological information.

Upper-air observations (radiosondes) were taken twice daily from Desert Rock Meteorological Observatory (DRA; elevation 1007 meters [m], located 4.8 kilometers southwest of Mercury, Nevada [Station 30 in Figure F.1]) but were discontinued in October 2010. Upper-air data are currently collected at the National Weather Service office in Las Vegas. DRA had been in operation since May 1978 and was built to replace a similar observatory that was located at the Yucca Flat Meteorological Observatory (UCC; elevation 1,196 m) from January 1962 through mid-May 1978. Consequently, surface and upper-air observations are also available from UCC for 1962–1978.

A key component of the MIDNET system is the MEDA station. A MEDA station consists of a 10-m tower, a data-logger, meteorological sensors, and a radio transmitter. The 23 MEDA stations located on or near the NNSS (Figure F.1) provide surface weather data for climatology, weather forecasts, and warnings for NNSS operations and emergency response activities. MEDA station locations were selected based on criteria to support NNSS consequence assessment activities, compliance reporting requirements, and general weather and forecasting needs.

Wind and temperature data have been collected on the NNSS for more than 40 years. These and other meteorological data have been compiled into a comprehensive climatological database for the NNSS. The MEDA data are especially useful in assessing boundary layer flow regimes on the NNSS.

The wind speed and direction sensor is located 10 m above the ground. Wind direction is measured to ±5 degrees of azimuth, and wind speed is accurate to 0.5 knots. Wind data are collected as 15-minute averages and are transmitted via radio and sent over the NNSS intranet to a central processor every 15 minutes. These data are reviewed by ARL/SORD and are stored and archived for climatological purposes.

Ambient temperature and relative humidity sensors are located approximately 1.5 m above ground level. MEDA temperature data are accurate to ±0.2 degrees Celsius (°C) (absolute range for the NNSS is −29°C to 46°C). Temperature and relative humidity measurements are 15-minute averages and are also transmitted via radio to a computer server for processing, review, display, and archiving.

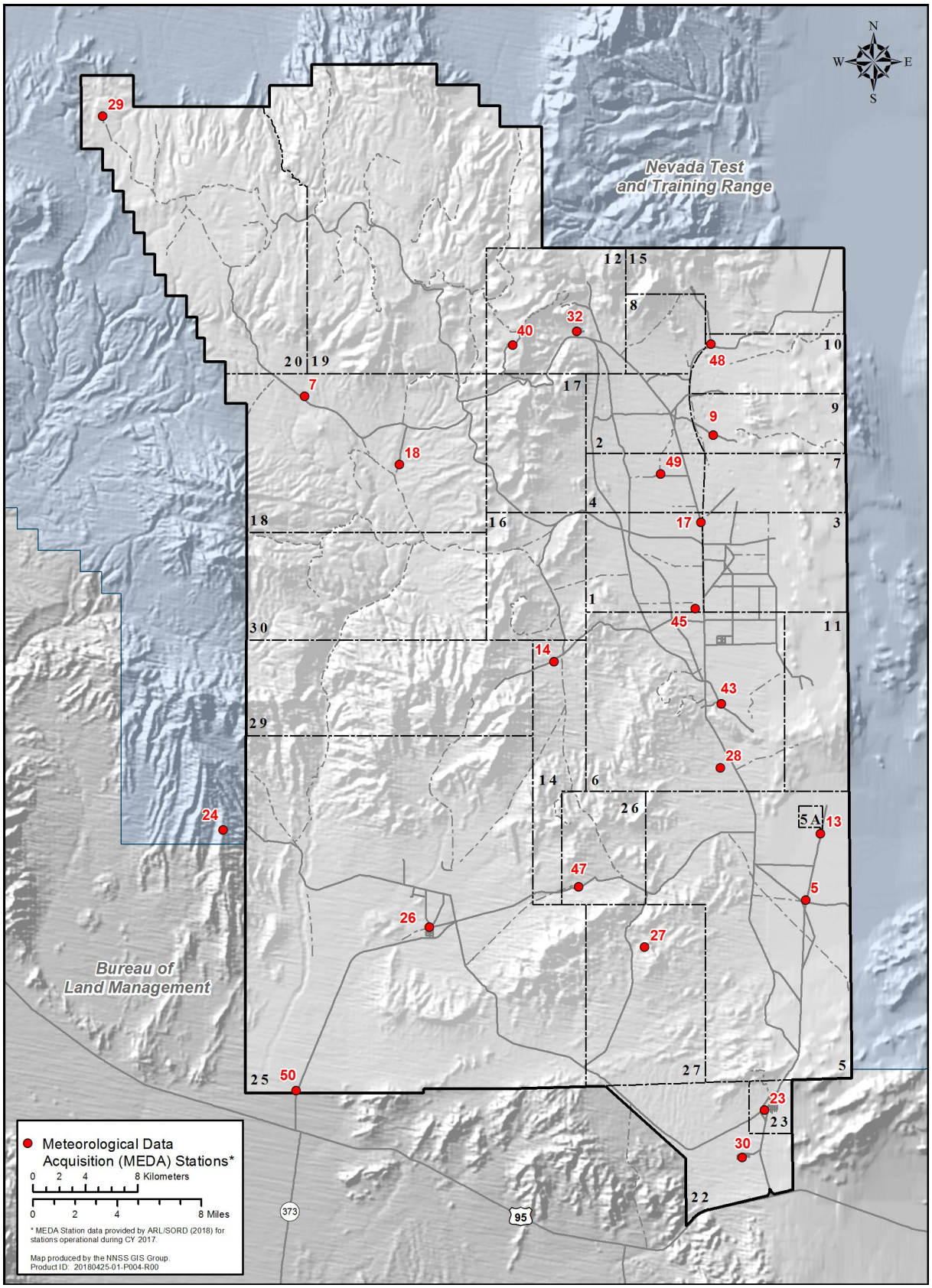

Figure F.1. Locations of MEDA Stations on the NNSS at End of CY 2019

Cloud cover observations are needed to create the Stability Array (STAR) files with the STAR program. In order to use the most representative meteorological data available for NNSS, cloud observations from DRA are melded with MEDA winds. Cloud data are available for DRA (1978–present) and for UCC (1962–1978). Based on the available data, the cloud cover climatology from DRA and UCC are quite compatible. For example, UCC experienced 192 clear days annually, while DRA has 191 days. In addition, the average annual sky cover from sunrise to sunset for both stations was/is 0.39 daily. The total number of cloudy days for UCC is 81 days and 82 days for DRA, annually. Therefore, the cloud cover observations from DRA and UCC may be considered as representative for most areas of the NNSS.

APPLICATION TO CAP88-PC INPUT

Based on the above considerations and on the limitations of the Clean Air Package 1988 (CAP88-PC) computer program, the cloud cover data from DRA are considered to be representative of the NNSS. Therefore, atmospheric soundings and cloud cover observations from DRA were melded with MEDA surface wind data for input to the STAR program to provide the best data for calculating transport and dispersion processes. The STAR file is a matrix that includes seven Pasquill stability categories (A through G), six wind speed categories, and 16 wind sectors from wind roses calculated for each specified MEDA station on the NNSS. The STAR files are used by a CAP88-PC utility program to create WIND files that are used by CAP88-PC to estimate offsite dose from NNSS emissions (Section III) and to emissions from diffuse tritium sources on the NNSS (Appendix B).

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Appendix G

Supplemental Information

COLLECTIVE EFFECTIVE DOSE EQUIVALENT

The collective effective dose equivalent (EDE) is the sum of the dose predicted by the CAP88-PC at each offsite receptor location multiplied by the population at that location. The collective EDE for CY 2019 was 0.29 person-rem [roentgen equivalent man] per year (y) for the 499,500 people who lived within 80 km (50 mi) of NNSS emission sources.

COMPLIANCE WITH 40 CFR 61, SUBPARTS Q AND T

The NNSS is regulated by Title 40 Code of Federal Regulations (CFR) Part 61, Subpart H ("National Emission Standards for Emissions of Radionuclides Other than Radon from DOE Facilities") but not Q ("National Emission Standards for Radon Emissions from DOE Facilities") or T ("National Emission Standards for Radon Emissions from the Disposal of Uranium Mill Tailings"). However, U.S. Department of Energy Order DOE O 435.1, "Radioactive Waste Management" (DOE 1999a) does include limits on radon flux from waste disposal facilities. Therefore, radon flux measurements are routinely made at the Area 3 Radioactive Waste Management Site and at the Area 5 Radioactive Waste Management Complex (RWMC). This is done to confirm that radon fluxes are below the standard of 20 picocuries per square meter per second required by U.S. Department of Energy Manual DOE M 435.1-1, "Radioactive Waste Management Manual" (DOE 1999b). The maximum radon flux measurement taken during 2019, at the Area 5 RWMC was 3.1 $pCi/m^2/s$. An assessment of the potential risks posed by the Area 5 RWMC to the public projected that the in-growth of radon-222 from the decay of thorium-230 in thorium wastes would not exceed the standard for approximately 4,200 years (National Security Technologies, LLC, 2013b).

NON-DISPOSAL/NON-STORAGE SOURCES OF RADON EMISSIONS

None of these sources exist on the NNSS.

QUALITY ASSURANCE PROGRAM FOR NESHAP COMPLIANCE

The quality assurance program for samples collected and analyzed for NESHAP compliance is documented in an environmental monitoring plan (DOE 2003). The applicable requirements of 40 CFR 61, Appendix B, Method 114, "Test Methods for Measuring Radionuclide Emissions from Stationary Sources" (U.S. Environmental Protection Agency 2001b) and of DOE O 414.1D, "Quality Assurance" (DOE 2011) have been implemented in this plan.