ORAU Team **NIOSH Dose Reconstruction Project** Technical Basis Document for the K-25 Site – Site Description	Document Number: ORAUT-TKBS-0009-2 Effective Date: 01/12/2004 Revision No.: 00 Controlled Copy No.: _____ Page 1 of 14
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ACRONYMS AND ABBREVIATIONS

AVLIS	Atomic Vapor Laser Isotope Separation
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ETTP	East Tennessee Technology Park
IREP	Interactive RadioEpidemiological Program
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
ORGDP	Oak Ridge Gaseous Diffusion Plant
PGDP	Paducah Gaseous Diffusion Plant
PWMP	Pond Waste Management Project
RU	recycled uranium
TBD	technical basis document
TRU	transuranic
TSCA	Toxic Substances Control Act

2.0 SITE DESCRIPTION

2.1 INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) was assigned the responsibility for developing the technical capabilities and guidance to be used to implement the Energy Employees Occupational Illness Compensation Program Act (EEOICPA). Oak Ridge Associated Universities (ORAU) led a team to support NIOSH. This technical basis document (TBD) represents a specific area of support to the ORAU Team concerning documentation of historical practices at the K-25 Site [also know as the Oak Ridge Gaseous Diffusion Plant (ORGDP) and the East Tennessee Technology Park (ETTP)] regarding evaluation of internal and external dosimetry data for unmonitored and monitored workers for use as a supplement to or substitute for individual monitoring data. Figure 2.1-1 is a map of the K-25 area.

2.1.1 PURPOSE

The purpose of this section is to provide a K-25 profile that contains technical basis information used by the ORAU Team to evaluate the total occupational dose for EEOICPA[1] claimants.

2.1.2 SCOPE

K-25 operations played an important role in the U.S. nuclear weapons program (DOE 1997). K-25 processes included uranium enrichment in the isotope uranium-235 (^{235}U), radiochemical processing, uranium recycling, and waste management. This TBD contains supporting documentation to assist in the evaluation of worker dose from these processes using the methodology described in NIOSH OCAS-IG-001, *External Dose Reconstruction Implementation Guideline* (NIOSH 2002a) and OCAS-IG-002, *Internal Dose Reconstruction Implementation Guideline* (NIOSH 2002b).

Methods and concepts of measuring radiation exposure to workers have evolved since the beginning of K-25 operations in 1945. An objective of this document is to provide supporting technical data to evaluate, with claimant-favorable assumptions, the total K-25 occupational dose that can reasonably be associated with worker radiation exposure as covered under the EEOICPA legislation. This dose includes occupational external and internal exposure in K-25 facilities; K-25 occupationally required diagnostic X-ray examinations, and onsite exposure to K-25 and other Oak Ridge Reservation environmental releases. The documentation addresses evaluation of unmonitored and monitored worker exposure, and missed dose. Consistent with NIOSH Implementation Guidelines, this document identifies how to adjust the historic occupational dose to account for current scientific methods and protection factors.

In addition, this document presents the technical basis of methods used to prepare K-25 worker dose records for input to the NIOSH Interactive RadioEpidemiological Program (IREP) and Internal Modular Bioassay Analysis computer codes used to evaluate worker dose. Information on measurement uncertainties is an integral component of the NIOSH approach. This document describes how the uncertainty for K-25 exposure and dose records is evaluated.

The following sections describe the facilities and processes, historic information related to worker internal and external exposures, and environmental data for use when actual monitoring data are

[1] EEOICPA, Public Law 106–398, provides for the payment of compensation benefits to covered employees and, where applicable, survivors of such employees of the U.S. Department of Energy, its predecessor agencies, and certain of its contractors and subcontractors.

unavailable. The attachments to this TBD contain critical data and tables required for individual claimant dose reconstructions. The attachments should suffice as a standalone document for dose reconstruction. Additional details, if necessary, are in the main body of the text.

2.2 SITE ACTIVITIES AND PROCESSES

The dates of operation of the K-25 facilities and activities described below are from *Recycled Uranium Mass Balance Project Oak Ridge Gaseous Diffusion Plant Site Report*, BJC/OR-584, June 2000.

The Oak Ridge Gaseous Diffusion Plant (ORGDP, or the K-25 Site), now known as the East Tennessee Technology Park (ETTP), processed thousands of tons of uranium through diffusion cascades for more than 40 years. The vast majority of the uranium was extracted and purified from ore, but some was recycled material obtained from spent reactor fuel.

The primary K-25 areas that enriched ^{235}U using the gaseous diffusion process include Cascade Buildings K-25, K-27, K-29, K-31, K-33, K-413, and K-631. Uranium was initially processed in series operation in Buildings K-25, K-27, and K-29. Buildings K-31 and K-33 were later placed in series operations with the existing cascade. When the enrichment process was active, the uranium in these areas was almost exclusively in the form of uranium hexafloride (UF_6).

The uranium processed in these areas originated both from natural ores and recycled uranium products. The uranium feed material whether natural or recycled uranium were purified before reaching K-25 and were chemically identical. Various natural sources were used but the uranium feed material was not source dependent. The recycled uranium contained trace amounts of activation and fission products that were not completely removed by the recovery and purification processes. The recycled feed material may have varied somewhat depending upon both time in the reactor and process of recovery.

Processing of recycled uranium from spent reactor fuel was intermittent, with campaigns conducted in 1952 to 1964, 1969 to 1974, and 1976 and 1977. Virtually all of the recycled uranium came from plutonium production reactors at the Hanford and Savannah River Sites, with little from power or demonstration reactors.

The material recycled from reprocessed reactor fuels contained trace quantities of fission products and transuranic (TRU) elements formed during irradiation of the fuels. Most of these impurities were removed during chemical processing of the fuels. Because fluorinated compounds of the elements in question have limited volatility, much of the impurity activity initially present remained in the feed cylinders or was deposited in the cascade equipment very close to the feed point. However, trace quantities passed through the chemical and physical separations to contaminate the diffusion cascades.

Process operations primarily resulted in ^{234}U, ^{235}U, and ^{238}U contamination. Characterization studies to date indicate the primary contaminants incident to the recycled uranium are technicium-99 (^{99}Tc), neptunium-237 (^{237}Np), americium-241 (^{241}Am), plutonium-238 (^{238}Pu), and $^{239/240}Pu$. The studies did not indicate significant amounts of other contaminants, such as beta/gamma-emitting fission products.

The U:TRU activity ratios tended to run greater than 1000:1 for samples containing significant contamination. There was an isolated instance in which the activity ratio of U:TRU was as low as 60:1 on a relatively low-activity sample from Building K-25-W. However, the weighted average U:TRU activity ratio for all samples was greater than 1000:1 for every process building. This is a good indication that uranium is the dominant radiological contaminant in these areas. The weighted

average distribution of TRU activity in samples from these buildings was approximately 16% ^{237}Np, 8% ^{241}Am, 43% ^{238}Pu, and 32% $^{239/240}$Pu.

However, the weighted average was strongly biased by one sample with the most activity from Building K-25-W. The weighted average of all other samples from all process buildings showed a TRU activity distribution of approximately 87% ^{237}Np, 3% ^{241}Am, 4% ^{238}Pu, and 6% $^{239/240}$Pu. This distribution supports the process expectation that, of the TRU radionuclides, neptunium fluoride is likely to have been the most mobile in the gaseous phase and traveled farther (although generally only a short way) in the process before being deposited. The others are likely to have been present in the feed in lower concentrations and to have remained more readily in the heels of the feed cylinders.

Technetium is similar to uranium in its chemical nature, and forms compounds that carry through the chemical separation processes to a significant degree. A number of its compounds are gaseous under cascade conditions and, being of lower molecular weight than UF_6, diffuse preferentially toward the enriched part of the cascade. These compounds were concentrated in the part of the equipment called the purge cascade. In this area, technetium was deposited in many items of equipment. During maintenance operations, some of these materials were spilled or released from the equipment (some in the gaseous state). This resulted in significant surface contamination in Units K-310-1, K-310-2, and K-310-3 of Building K-25 and Units K-402-1, K-402-8, and K-402-9 of Building K-27. In addition, an accidental release from a stripping system in Building K-29 resulted in significant technetium surface contamination of the cell floor. Characterization studies to date indicate that the observed activity ratio of U:Tc has been as low as 0.002:1 in these areas. Activity ratios less than 1:1 for U:Tc are common in these areas, indicating that ^{99}Tc contamination is significant.

2.2.1 K-25 Processing History

August 1945 to January 1946
The original cascade configuration was established in August 1945 when all stages of the K-25 building came “on stream.” All feed that entered the cascade during this period was natural UF_6.

January 1946 to 1948
In early 1946, Building K-27 construction was completed, and its units were placed on stream as quickly as feasible. All feed that entered the cascade during this period was natural UF_6.

1948 to 1951
The efficient production of 93% ^{235}U required lengthening of the ORGDP enrichment cascade. This modification resulted in a significant change to the K-25/K-27 cascade configuration. All feed that entered the cascade during this period was natural UF_6.

1951 to 1952
The third major processing building was K-29, which was east of Building K-27. All feed that entered the cascade during this period was natural UF_6.

1952 to 1954
The Paducah Gaseous Diffusion Plant (PGDP) was brought on stream during this period. The overall optimum cascade configuration was an overlap between the PGDP and ORGDP sites. PGDP was used for the low-assay range of the enrichment process. Recycled uranium (RU) was first received at ORGDP in 1952 and was fed into the cascade in 1953.

1954 to 1957

Building K-33 came on stream as the ORGDP expansion continued. ORGDP processed a few reactor returns in 1955, and continued to receive product from PGDP for use as feed.

1957 to 1959
The cascades (feed and withdrawal points) were modified during this period. ORGDP processed reactor returns in 1959, and continued to receive product from PGDP for use as feed.

1959 to 1961
The ORGDP powerhouse was shut down and modifications of the cascade were made for efficiency. The remaining cascade configuration and feed and withdrawal points did not change. ORGDP processed reactor returns throughout this period, and continued to receive product from PGDP for use as feed.

1962 to 1964
No cascade modifications occurred during this period, but ORGDP feed and tails withdrawal were modified. Feed and tails removal operations occurred in a single building. ORGDP processed reactor returns during this period, and continued to receive product from PGDP for use as feed.

1964 to 1985
In 1964, Buildings K-25 and K-27 were shut down, with the exception of the K-25 purge cascade and its pigtail operation. In 1968, part of Building K-29 was shut down. The bottom of the cascade was now in Building K-31. ORGDP processed reactor returns through 1984, and continued to receive product from PGDP for use as feed. In June 1985, ORGDP was placed on standby; in 1987, the plant was shut down permanently.

2.2.2 Facilities and Support Locations

The K-25 area included support facilities that processed or stored radioactive materials. The identities, relative abundances, and chemical forms of radionuclides in the different work areas are presented in characterization studies for the transformation of K-25 to ETTP (DOE 1994). The following paragraphs summarize these studies.

Uranium solubility class varied with process, but the residual RU radionuclides were typically as listed in Table 2.2.2-1. Radionuclides with more than one class listed tended to follow the uranium at the respective area (^{99}Tc of class F followed uranium class F and M, while ^{99}Tc of class M followed uranium of class M and S). The isotopes of curium are not discussed in the descriptions below, but was general present at a lesser amount than the listed TRU. ^{230}Th was not measured at any location, but ingrowth from ^{234}U should make ^{230}Th marginally significant at some locations for intakes since about 1990. The radiological hazards by area are listed in Table 2.2.2-2 with the corresponding uranium solubility class.

Gaseous Diffusion Plant and Feed Materials Process Areas
The gaseous diffusion process included Cascade Buildings K-25, K-27, K-29, K-31, K-33, K-413, and K-631. The physical form of uranium in these areas was almost exclusively UF_6 during the active years. During the inactive years, any residual UF_6 has reacted with atmospheric moisture, forming the compound UO_2F_2, which is solubility Class F, but may have further reacted to Class M. No process history is indicative of appreciable Class S uranium compounds.

RU processing resulted in contaminants of ^{99}Tc, ^{237}Np, ^{241}Am, ^{238}Pu, and $^{239/240}$Pu. Significant amounts of other contaminants, such as beta-gamma-emitting fission products, were not revealed in the studies.

K-1131
K-1131 initially produced UF_6 from virgin and recycled uranium oxides. It also produced the compound UF_4 as an intermediate step toward the final product. Later, the facility was used for feed vaporization and tails withdrawal.

The radionuclides in this area were the result of UF_6 production and from the introduction of recycled uranium material. Isotopes present were ^{234}U, ^{235}U, ^{238}U, ^{99}Tc, ^{237}Np, ^{241}Am, ^{238}Pu, and $^{239/240}Pu$. There were no significant amounts of beta/gamma-emitting fission products. Samples from this facility exhibited lower U:TRU activity ratios than those taken in most other areas. One sample produced a U:TRU activity ratio as low as 50:1. However, the facility-weighted average was 244:1. The composition of TRU material in this facility is consistent with the process expectation, showing a weighted average of approximately 60% ^{237}Np, 12% ^{241}Am, 22% ^{238}Pu, and 7% $^{239/240}Pu$. The observed activity ratio of U:Tc has been as low as 30:1, which is an indication that uranium tends to dominate technetium in this area.

The process history of this area is consistent with that of lung solubility type Class F uranium compounds. Nothing about the fluorination process history suggests the presence of lung solubility type Class S uranium compounds to an appreciable extent.

K-1420 Decontamination Facility
The K-1420 Decontamination Facility initially supported decontamination, plating, and uranium recovery operations. It is still in use as a decontamination facility. The U.S. Department of Energy (DOE) used this facility to decontaminate equipment from K-25 and materials from other sites. The history of this facility suggests that Class F, M, and S uranium compounds could be present. Because the uranium recovery operation involved calcining procedures, Class F and Class S uranium compounds could have formed in this portion of the facility.

The isotopes found were ^{234}U, ^{235}U, ^{238}U, ^{99}Tc, ^{237}Np, ^{241}Am, ^{238}Pu, and $^{239/240}Pu$. Significant amounts of beta/gamma-emitting fission products were not present. Samples from this facility exhibited lower U:TRU activity ratios than those from most other areas. Three samples showed U:TRU activity ratios less than 100:1, with one sample as low as 43:1. The composition of TRU material in this facility deviates from the K-25 Site average composition. Samples taken at this facility showed a weighted average of approximately 15% ^{237}Np, 8% ^{241}Am, 4% ^{238}Pu, and 73% $^{239/240}Pu$. The high plutonium contribution could be the result of contamination from the cylinder wash area because plutonium tends to stay in the cylinder heels. The observed activity ratio of U:Tc has been as low as 0.5:1.

K-1410 Decontamination and Plating Facility
The K-1410 Decontamination and Plating Facility was used for various purposes, including storing clean trapping material, and dumping, cleaning, and refilling diffusion cascade traps; as a cleaning and decontamination facility before the construction of K-1420; and as an electroplating facility. Materials decontaminated at the K-1410 Facility include K-1131 Feed Plant equipment used to process Hanford reactor returns and S-50 Liquid Thermal Diffusion Process materials and equipment. In addition, records indicate that ash receivers from K-1131 were stored in and around K-1410. The process history indicates that the presence of Classes F, M, and S uranium is probable.

This area was not well characterized but the usual isotopes from natural and reactor return uranium occur.

K-1037 AVLIS Experiment Facility
The mission of this facility was to demonstrate the feasibility of the Atomic Vapor Laser Isotope Separation (AVLIS) ^{235}U enrichment process on a production scale. This process, which is no longer

active, used metallic uranium; therefore, the isotopes of concern are ^{234}U, ^{235}U, and ^{238}U. No recycled uranium was processed at this facility and, therefore, significant TRU or ^{99}Tc activity is unlikely. Contamination characterization studies to date have not revealed the presence of significant quantities of recycle-type contaminants. Process history dictates that uranium compounds in this area are Class S.

K-1015 Laundry Facility
This facility laundered anticontamination clothing from K-25 and the Y-12 Plant. The isotopes ^{234}U, ^{235}U, and ^{238}U are of primary concern and of likely all solubility classes.

It is reasonable to expect the presence of radioactive materials other than uranium in this facility. However, recent characterization has not found RU radionuclides.

K-1066 Cylinder Yards
DOE stores UF_6 cylinders in the K-1066 Cylinder Yards. Nondestructive measurements of "rust" from cylinders in the K-1066-B Cylinder Yard, performed by gamma spectroscopy, have shown an average uranium-to-^{237}Np activity ratio of 159:1. Analyses for ^{241}Am and plutonium did not occur. Lower U:TRU activity ratios would be likely in recycle feed cylinders because much of the TRU material is likely to remain in the heel of the cylinder. Class F or M uranium compounds would be likely for this type of contamination.

K-1435 TSCA Incinerator
This is an active facility designed to dispose of toxic waste substances by high temperature incineration. Trace amounts of radioactive material are contained in the process stream. This facility receives wastes from Oak Ridge locations other than K-25 as well as from other DOE installations. The primary contaminants of interest are ^{234}U, ^{235}U, and ^{238}U, although traces of other isotopes are present in the waste processed at this facility. Contamination characterization studies to date have not revealed the presence of any significant quantities of recycle-type contaminants. However, characterization is performed on the waste fed to the incinerator, which in turn can be used to characterize the isotopic composition of potential contamination. The Annual TSCA Incinerator Rolling Totals Report for 1995 shows a U:TRU activity ratio of 260:1 based on analysis for ^{237}Np, ^{238}Pu, and ^{239}Pu. However, if ^{228}Th, ^{230}Th, and ^{232}Th are included with the TRU, a ratio of 65:1 is obtained. Therefore, this activity ratio will be assumed for this facility. The nature of the incineration process can reasonably be expected to concentrate radioactive contaminants in residue-handling equipment. It is possible that the incineration temperatures could convert relatively soluble compounds into relatively insoluble forms. Therefore, Class S uranium is presumed to exist in the residue-handling equipment. Areas and equipment where residues are not processed are presumed to contain Class F or MW uranium compounds.

K-1064, K-1417, K-1419
Waste drums containing sludge dredged from two settling ponds, K-1407 B and C, which received waste from the K-1420 operations, were stored near the K-1420 Facility. The Pond Waste Management Project (PWMP) has been involved in the fixation of this waste in cement. Facility K-1064 is the PWMP Cement Truck Area; K-1417 is the PWMP Barrel Yard; and K- 1419 is the Sludge Fixation Facility. These areas have potential contamination from the K-1435 TSCA Incinerator. Analysis of this waste showed U:TRU activity ratios consistently less than 50:1. The weighted average U:TRU activity ratio was 16:1. The samples taken showed a weighted average of approximately 49.5% ^{237}Np, 1% ^{238}Pu, and 49.5% 239/240Pu. Analysis for ^{241}Am was not performed. Since this waste was generated from operations at K-1420, it is reasonable to expect that uranium may exist in both Class M and S compounds.

Other Facilities

Other support buildings (including the K-1401 Maintenance Facility, the K-1231 Uranium Recovery Facility, and the K- 1004 and K-1006 Laboratory Facilities) generally contained less removable contamination. Isotopic activity ratios could not be accurately determined. However, the weighted average U:TRU activity ratio for samples taken from these areas was greater than 1000:1. Therefore, all other areas of the ETTP are assumed to have an isotopic distribution similar to the main process buildings. However, operations at K-1004, K-1006, and K-1008-C are assessed to have the potential to produce contamination from Class S uranium in addition to Class F and M.

REFERENCES

BJC/OR-584, Recycled uranium mass Balance Project Oak Ridge Gaseous Diffusion Plant Site Report, June, 2000.

DOE (U.S. Department of Energy), Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes To Their Environmental Consequences, published January 1997.

DOE 1994, Assessment of Accessible Contamination at the K-25 Site Phase 3 Report: Cumulative Analytical Results, K/HS-570, Oak Ridge K-25 Site, May 1994.

NIOSH (National Institute for Occupational Safety and Health, 2002a, External Dose Reconstruction Implementation Guideline, OCAS-IG-001,

NIOSH (National Institute for Occupational Safety and Health, 2002b, Internal Dose Reconstruction Implementation Guideline, OCAS-IG-002,

GLOSSARY

Anticontamination clothing
Outer clothing to prevent contamination of the skin and under clothing.

AVLIS
Atomic Vapor Laser Isotope Separation, a process for enriching ^{235}U by ionizing uranium compounds in a vapor based on a laser tuned to the electronic structure of uranium compounds.

Recycled uranium (RU)
Uranium that was irradiated in a reactor to produce plutonium. The uranium was chemically separated and purified, but contained minor amounts of TRU and fission products. ^{99}Tc was the major fission product.

TSCA
Toxic Substances Control Act is a U.S. law that governs the disposal of toxic substances. Material at K-25 that contain both radionuclides and toxic substances are burned in a TSCA compliant incinerator.

Table 2.2.2-1. Solubility class of RU radionuclides

Isotope	Solubility Class
^{230}Th	M,S
$^{238/239/240}$Pu	M,S
^{237}Np	M
$^{242/244}$Cm	M
^{241}Am	M
^{99}Tc	F,M

Table 2.2.2-2. K-25 radiological hazards by area

Site Facilities	Uranium Inhalation Class	TRU Present	^{99}Tc Present
Gaseous Diffusion Plant	F,M	Yes	Yes
Feed Materials Processing Areas	F,M	Yes	Yes
K-1131	F	Yes	Yes
K-1420 Decon Facility	F,M,S	Yes	Yes
K-1410 Decon & Plating	F,M,S	Yes	Yes
K-1064, K-1417, K-1419	M,S	Yes	Yes
K-1037 AVLIS	S	No	No
K-1435 TSCA Incinerator	F,M,S	Yes	Yes
K-1015 Laundry Facility	F,M,S	Yes	Yes
K-1066 Cylinder Storage Yards	F,M	Yes	Yes
K-1004, K1006, K1008C	F,M,S	Yes	Yes

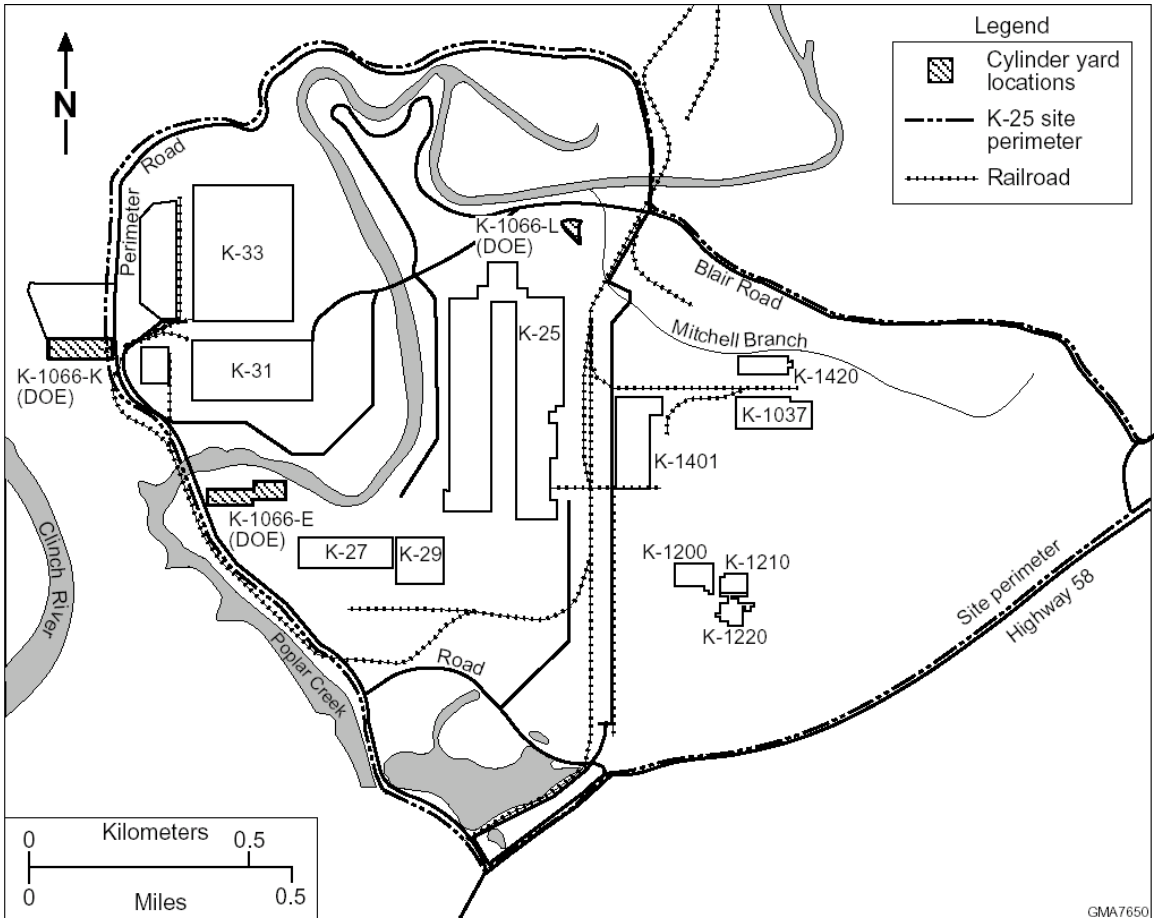

Figure 2.1-1. Map of the K-25 area showing major facilities.