ORAU Team **NIOSH Dose Reconstruction Project** Technical Basis Document for the Y-12 National Security Complex – Occupational Environmental Dose	Document Number: ORAUT-TKBS-0014-4 Effective Date: 10/11/2005 Revision No.: 00 PC-3 Controlled Copy No.:_____ Page 1 of 47
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RECORD OF ISSUE/REVISIONS

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12/05/2003	12/05/2003	00	New document to establish Occupational Environmental Dose, Section 4. First approved issue. Initiated by William E. Murray.
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ACRONYMS AND ABBREVIATIONS

ASER	Annual Site Environmental Report
Bq	becquerel
cm	centimeter
CEDR	Comprehensive Epidemiologic Data Resource
Ci	curie
DOE	Department of Energy
DU	Depleted Uranium
EU	Enriched Uranium
EPA	Environmental Protection Agency
FP	Fission products
g	gram
GM	Geometric mean
GSD	Geometric standard deviation
h	hour
kg	kilogram
LAM	Local area monitoring
m	meter
MMES	Martin Marietta Energy Systems
NESHAP	National Emission Standards for Hazardous Pollutants
ORAU	Oak Ridge Associated Universities
ORDR	Oak Ridge Dose Reconstruction
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
OSTI	Office of Scientific and Technical Information
PAM	Perimeter air monitoring
RAM	Remote air monitoring
TDEC	Tennessee Department of Environment and Conservation
TRU	Transuranics
U.S.C.	United States Code
Y-12	Y-12 National Security Complex
y	Year
µCi	microcurie
µg	microgram
µR	microroentgen

4.1 Introduction

Technical Basis Documents and Site Profile Documents are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 (42 U.S.C. § 7384l (5) and (12)). EEOICPA defines a DOE facility as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)." 42 U.S.C. § 7384*l*(12). Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For DOE employees with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision (42 U.S.C. § 7384n(b)) says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the [probability of causation] guidelines established under subsection (c) …." 42 U.S.C. § 7384n(b). Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program." 42 U.S.C. § 7384*l*(12). While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer (i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty") does not contain such an exclusion. Therefore, the statute requires NIOSH to include all radiation exposures in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction.

The occupational environmental dose received by unmonitored workers is limited to exposures received while outside buildings and within the perimeter of the Y-12 National Security Complex. Buildings and other operational units occupy the vast majority of the land area at Y-12. This assessment will quantify exposure for unmonitored workers who either work outdoors or otherwise spend time outside buildings. Based on the exposure assessment, the two exposure pathways are:

1. Inhalation of uranium in ambient air due to operational releases,

2. Direct external radiation from radionuclides in soils and outdoor surfaces, as well as shine from buildings and operational units.

Due to the complexity of the terrain surrounding Y-12 and the release mechanisms from the production facilities compounded by the limited dispersion distances, traditional dispersion and transport models were considered unsuitable. An empirical approach based on the limited ambient air monitoring at Y-12 was used to estimate uranium air concentrations. This approach used the annual release estimates independently reconstructed by previous studies to generate annual air concentrations for four locations within Y-12.

External exposures were estimated using the results of a comprehensive radiological scoping survey (Foley and Carrier 1990). The analysis of the results from the scoping survey generated a statistical range of exposure values.

4.1.1 Ambient Air Monitoring at Y-12

A review of the history of environmental monitoring was conducted of the historical ambient air monitoring data at Y-12. The quality of collected data was then evaluated to assess its usability for the purposes of evaluating intakes by workers. The review identified likely sources of information for ambient air monitoring data for both the Oak Ridge Reservation (ORR) and Y-12 . Relevant reports were identified from a number of libraries including the:

- Comprehensive Epidemiologic Data Resource (CEDR) maintained by the U.S Department of Energy (DOE),
- Energy Citations Database, developed by the DOE, Office of Scientific and Technical Information (OSTI),
- Oak Ridge Associated Universities (ORAU),
- Oak Ridge National Laboratory (ORNL),
- Oak Ridge Annual Site Environmental Reports (ASER), and
- DOE Oak Ridge Operations (ORO) Public Reading rooms.

In addition, discussions with persons familiar with the environmental monitoring activities at Y-12 and the Oak Ridge Reservation were conducted to identify other likely sources of information.

4.1.2 Chronology of Ambient Air Monitoring Activities

As the Y-12 facility has been operational for many years, there is no single source of ambient air monitoring information. This section presents a brief summary of ambient air monitoring activities specific to Y-12. No information on ambient air monitoring prior to 1959 was identified that was useful for this section. A detailed summary of air monitoring data including the source of information, the period of coverage, the type of available data, and the monitoring locations is presented in Table 4.1.2-1.

1959 – 1970: Applied Health Physics and Safety Reports

A series of Applied Health Physics Reports were identified that were published by the Health Physics Division of the ORNL. These reports were issued on a quarterly basis (entitled "*Environmental Levels*

of Radioactivity for the Oak Ridge Area") and summarized in annual reports ("*Applied Health Physics and Safety Annual Reports"*). Data collected by the team may have been from either source (or both) as not all reports were readily available. The air concentrations presented in these reports were collected from a system of air monitoring stations established and maintained by ORNL. These stations were used to provide data in determining the dispersal of contamination should a major incident occur. A review of the data presented in these reports indicates that the purpose of these stations was to monitor the concentrations of fission products from operations at ORNL.

There were three networks of monitoring stations initially established by ORNL:

1. A system of ten stations was located within the perimeter of ORNL: **Local Air Monitoring (LAM)** network.

2. Seven stations were initially established around the ORR known as the **Perimeter Air Monitoring (PAM)** network. The number of stations within the PAM was later increased to nine.

3. A third system of eight stations was established at distances of 12 to 120 miles from ORNL; this system was known as the **Remote Air Monitoring (RAM)** network.

Prior to 1983, the closest air monitoring station to Y-12 was the Midway Gate station which was part of the ORNL PAM network. This health physics station, initially designated as HP-12 (later renamed HP-32), was located north of the intersection of Bear Creek Road and Lafayette Drive (Figure 4.1.2-1). A second station (HP-11) was located on Bethel Valley Road (Kerr Hollow). This station is far removed from the Y-12 facility and it is unlikely to provide relevant data. These stations are the only known locations for ambient air monitoring data in the vicinity of the Y-12 facility prior to 1983.

Samples were collected at HP-12/HP-32 by passing air continuously through a filter paper which would only accumulate particles considered to be respirable. Sample collection frequency varied during this period. However, most of the samples were collected weekly. Estimated concentrations were compared to maximum permissible concentrations to determine if further analyses were warranted.

Earlier available data for this station (HP-12/HP-32) were characterized as "Activity" or as "Long-lived Activity." No further characterization was available in the published reports. Gross β data was first available in 1963 and gross α results were first reported in 1965 (Table 4.1.2-1).

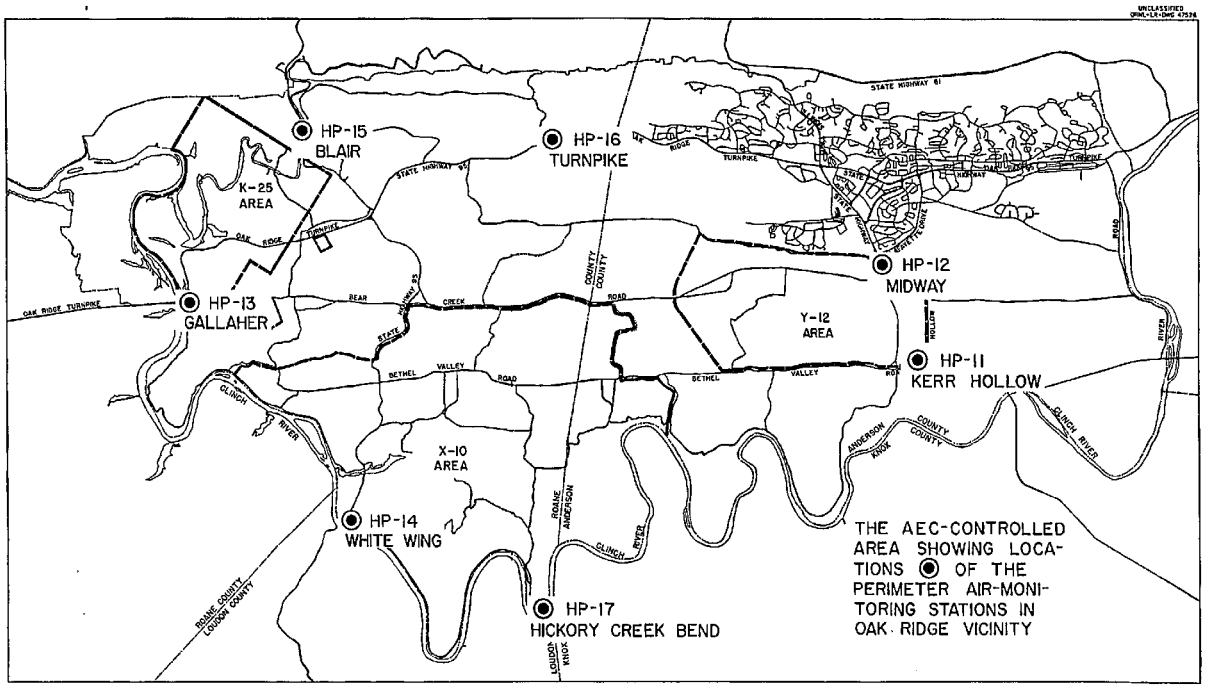

Figure 4.1.2-1. Locations of ORNL Perimeter Air Monitoring (PAM) Stations. Station HP-12 at Midway Gate (later renamed HP-32) is the closest station to the Y-12 facility prior to 1983 (Abee 1961).

1971 – 1983: Environmental Monitoring Reports

This series of reports covers all the ORR facilities and the stations initially established by ORNL. A number of new stations established north of Y-12, were used to measure fluorides, sulfur and dust-fall. Station HP-32 (previously designated HP-12) at the Midway Gate continued to be the only health physics monitoring station closest to Y-12. Data collected and presented in these reports for HP-32 (Midway Gate) was limited to gross α and gross β as shown in Table 4.1.2-1 and a detailed analysis was performed only if the concentrations were above established maximum permissible concentrations.

Uranium activity in air was reported beginning in 1975. However, the reported concentration was based on a composite sample taken from all stations with the PAM network. In 1975, high concentrations of ambient uranium were noted and were attributed to enrichment and processing activities at the Oak Ridge Gaseous Diffusion Plant (ORGDP) and Y-12. The elevated concentrations also noted in 1976 were attributed to operational problems with the pollution control on the purge cascade at ORGDP. Since these values were averaged for all PAM stations, no direct relationship to the operations at Y-12 could be made from these data sets. It is likely that data specific to Station HP-32 were collected. However, these data were not reported in any of the reports reviewed.

Two changes in the air monitoring network were noted in 1983:

1. A second monitoring station was established east of Y-12. This station initially designated HP-40 (later re-designated Station 40) was located along Bear Creek road at the northeast corner of the perimeter of the Y-12 facility (Figure 4.1.2-2). Samples collected at this station were analyzed for gross α and gross β activity and iodine-131 (^{131}I), along with other radionuclides

including fission products (FP), uranium and transuranics (TRU). These concentrations were averaged for all stations in the PAM network.

2. The second major change was the establishment of the eleven air monitoring stations in and around the perimeter of Y-12. These stations were established primarily to measure uranium. The location and operation of these stations is further described in the next section.

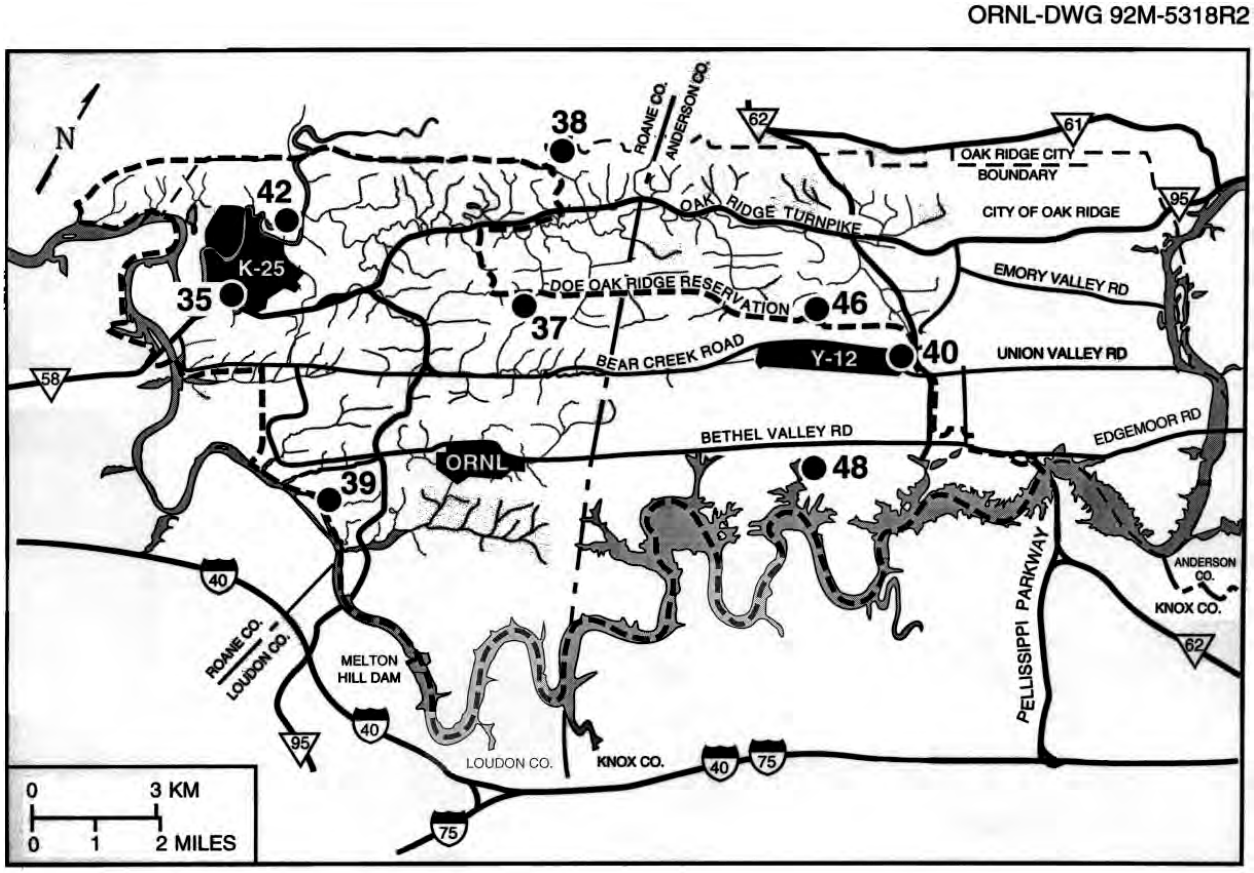

Figure 4.1.2-2. Location of Station 40 incorporated into the ORNL Perimeter Air Monitoring (PAM) network in 1983. Station is located at the northeast perimeter of the Y-12 facility (DOE 2002).

1984 – 1999: Annual Monitoring Report / Annual Site Environmental Report

After 1984, the amount of environmental monitoring increased substantially and this period is the most significant for uranium air monitoring at Y-12. The air monitors established in and around the Y-12 perimeter, which began operations in 1983, were primarily for the measurement of uranium. Sampling for radioactive particulates was conducted by passing air continuously through filter papers. These filters were evaluated weekly for gross α and gross β activity. The filters were composited quarterly and were evaluated for four uranium isotopes (^{234}U, ^{235}U, ^{236}U and ^{238}U). Reports from 1988 onward indicate that the filters were analyzed using alpha spectroscopy. No information on the analytical techniques employed before 1988 was immediately available. The Y-12 perimeter stations were increased to 12 stations beginning in 1985. The location of these stations is shown in Figure 4.1.2-3.

Note that for 1985 and 1986, these stations were initially designated as A61 through A71. A twelfth station (Station 12, formerly A72) was added in 1985; however, this station was initially used to

measure suspended particulates. Ambient uranium measurements at this station did not commence until 1987. With the establishment of the twelfth station, these stations were re-designated as Y-12

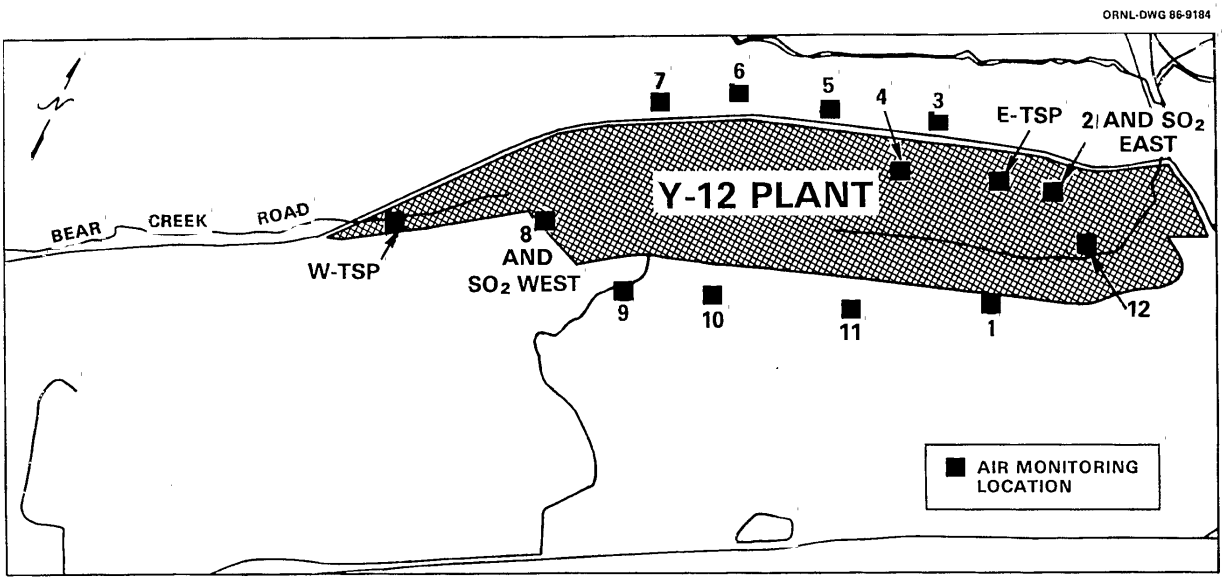

Figure 4.1.2-3. Locations of the twelve Y-12 perimeter air monitoring stations (DOE 1990)

Stations 1 through 12. Ambient uranium data for the twelve Y-12 stations included gross α and gross β and activity concentrations (μCi cm^{-3}) for four uranium isotopes (^{234}U, ^{235}U, ^{236}U and ^{238}U).

In 1993, the analysis program for radionuclides was revised to obtain total uranium (μg m^{-3}) concentrations and the percentage of ^{235}U. This approach was implemented to better correlate air concentrations with the stack emission data that were measured in terms of uranium mass. As shown in Table 4.1.2-2, data subsequent to, and including 1993, are reported in terms of μg m^{-3}.

Since there were no Federal or State regulations, or DOE Orders that required the monitoring of uranium releases, and with the reduction of plant operations, the usefulness of the Y-12 stations was re-evaluated in 1993. With the installation of an ambient air monitoring station at the Scarboro community (located north of Y-12), the Y-12 stations were considered redundant. In addition, processes that resulted in the emission of enriched and depleted uranium were equipped with stack samplers that were reviewed and approved by the Environmental Protection Agency (EPA) to meet the requirements of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations. Therefore, sampling at all but three of the stations (4, 5, and 8) was discontinued after 1994.

2001-2002: Tennessee Department of Environment and Conservation

With an agreement reached with the Tennessee Department of Environment and Conservation (TDEC), TDEC personnel took over responsibility for sampling and analysis of the remaining three uranium air sampling stations.

Samples collected from the three remaining Y-12 Stations (4, 5 and 8) by TDEC are only analyzed for gross α and gross β. Gamma spectrometry was performed only on samples that exhibited elevated gross results. Consequently, uranium air concentrations were no longer available after 1999.

Table 4.1.2-1. Summary of air monitoring data from stations at and surrounding the Y-12 facility.

Year	Reference	Off site health physics stations[1]				Y-12 on site air monitoring stations[1]				
		Activity/fission products	Gross α	Gross β	Uranium isotopes[2]	Gross α	Gross β	Uranium isotopes[2]	Total uranium activity (μCi cm^{-3})	Total uranium mass (μ g cm^{-3})
1959	Abee 1960a	HP-12	—	—	—	—	—	—	—	—
1960	Abee 1960b, Abee 1961, ORNL 1960	HP-12	—	—	—	—	—	—	—	—
1961	ORNL 1962	HP-12	—	—	—	—	—	—	—	—
1962	ORNL 1963	HP-32	—	—	—	—	—	—	—	—
1963	ORNL 1964a, ORNL 1964b	HP-32	—	HP-32	—	—	—	—	—	—
1964	ORNL 1965a, ORNL 1965b	—	—	HP-32	—	—	—	—	—	—
1965	ORNL 1966b	HP-32	HP-32	HP-32	—	—	—	—	—	—
1966	ORNL 1967c, ORNL 1967a	HP-32	HP-32	HP-32	—	—	—	—	—	—
1967	ORNL 1968c, ORNL 1968a	HP-32	HP-32	HP-32	—	—	—	—	—	—
1968	ORNL 1969a, ORNL 1969b, ORNL 1969c	HP-32	HP-32	HP-32	—	—	—	—	—	—
1969	ORNL 1969d, ORNL 1969e, ORNL 1970	HP-32	HP-32	HP-32	—	—	—	—	—	—
1970	ORNL 1971	HP-32	—	—	—	—	—	—	—	—
1971	UCC 1972	—	HP-32	HP-32	—	—	—	—	—	—
1972	UCC 1973	—	HP-32	HP-32	—	—	—	—	—	—
1973	UCC 1974	—	HP-32	HP-32	—	—	—	—	—	—
1974	UCC 1975	—	HP-32	HP-32	—	—	—	—	—	—
1975	UCC 1976	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1976	UCC 1977	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1977	UCC 1978	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1978	UCC 1979	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1979	UCC 1980	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1980	UCC 1981	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1981	UCC 1982	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1982	UCC 1983	—	HP-32	HP-32	PAM Composite[3]	—	—	—	—	—
1983	MMES 1984	—	HP-32 and HP-40	HP-32 and HP-40	PAM Composite[3]	—	—	—	Y-12 Stations: 1 -11	—
1984	MMES 1985	—	Station 40	Station 40	PAM Composite[3]	—	—	—	Y-12 Stations: 1 -11	—

Table 4.1.2-1. (Continued)

Year	Reference	Off site health physics stations[1]				Y-12 on site air monitoring stations[1]				
		Activity/fission products	Gross α	Gross β	Uranium isotopes[2]	Gross α	Gross β	Uranium isotopes[2]	Total uranium activity (μCi cm^{-3})	Total uranium mass (μ g cm^{-3})
1985	MMES 1986	—	Station 40	Station 40	PAM Composite[3]	Y-12 Stations: 1 -11	Y-12 Stations: 1 -11	Y-12 Stations: 1 –11	—	—
1986	DOE 1987a, DOE 1987b	—	Station 40	Station 40	Station 40	Y-12 Stations: 1 -11	Y-12 Stations: 1 -11	Y-12 Stations: 1 -11	—	—
1987[4]	DOE 1988a, DOE 1988b	—	Station 40	Station 40	Station 40	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	—	—
1988	DOE 1989	—	Station 40	Station 40	Station 40	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	—	—
1989	DOE 1990	—	Station 40	Station 40	Station 40	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	—	—
1990	DOE 1991	—	Station 40	Station 40	Station 40	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	—	—
1991	DOE 1992a, DOE 1992b	—	Station 40	Station 40	Station 40	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	—	—
1992[5]	DOE 1993a, DOE 1993b	—	—	—	Station 40	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	Y-12 Stations: 1 –12	—	—
1993	DOE 1994	—	—	—	PAM Composite[3]	—	—	—	—	Y-12 Stations: 1 –12
1994	DOE 1995	—	—	—	Station 40	—	—	—	—	Y-12 Stations: 1 –12
1995	DOE 1996	—	Station 40	Station 40	Station 40	—	—	—	—	Y-12 Stations: 4, 5, and 8
1996	DOE 1997	—	Station 40	Station 40	Station 40	—	—	—	—	Y-12 Stations: 4, 5, and 8
1997	DOE 1998	—	Station 40	Station 40	Station 40	—	—	—	—	Y-12 Stations: 4, 5, and 8
1998	DOE 1999	—	Station 40	Station 40	Station 40	—	—	—	—	Y-12 Stations: 4, 5, and 8
1999	DOE 2000	—	—	—	Station 40	—	—	—	—	Y-12 Stations: 4, 5, and 8
2000[6]	DOE 2001	—	—	—	Station 40	Y-12 Stations: 4, 5, and 8	Y-12 Stations: 4, 5, and 8	—	—	—
2001[6]	DOE 2002	—	—	—	Station 40	Y-12 Stations: 4, 5, and 8	Y-12 Stations: 4, 5, and 8	—	—	—

NOTES

1. Station HP-12 was the initial designation for the ORNL Perimeter Air Monitoring (PAM) Station at the Midway Gate, located northeast of Y-12. After 1961, HP-12 was renumbered HP-32. After 1984, HP-12 was relocated closer to Y-12 and was re-designated as Station 40. Y-12 Stations 1 - 12 (initially designated A61-A72) are located in and around Y-12 .
2. Isotopes measured were ^{234}U, ^{235}U, ^{236}U and ^{238}U.
3. Ambient air concentrations only reported as an average for ALL stations within the PAM network.
4. Units used for uranium data presented in Volume 1 of the 1987 report (DOE 1988a) are incompatible with similar data presented in Volume 2 for the same year (DOE 1988b). Error is most likely due to units used in Volume 1 as units used in Volume 2 are consistent with preceding and proceeding years.
5. Incompatibility of data values between annual average uranium concentrations presented in Volume 1 of 1992 Annual Site Environmental Report (DOE 1993a) and quarterly data presented in Volume 2 of same year (DOE 1993b). No Errata were found for this year. Therefore, the averages presented in Volume 1 were used. Station 10 data were missing for U-235 from volume 1. Average is calculated from quarterly data presented in Volume 2.
6. Responsibility for Y-12 stations 4, 5 and 8 was transferred to the Tennessee Department of Environment and Conservation (TDEC). Samples collected were analyzed for gross α and gross β only. Uranium analysis is only performed if gross measurements are elevated.

Table 4.1.2-2. Availability of uranium air concentration data measured at the twelve Y-12 air monitoring stations.

Year	Reported uranium data	Units	Y-12 monitoring station											
			1	2	3	4	5	6	7	8	9	10	11	12
1983	Total Activity	$\mu Ci\ mL^{-1}$												
1984	Total Activity	$\mu Ci\ mL^{-1}$												
1985	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1986	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1987[2]	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1988	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1989	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1990	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1991	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1992	Isotopic[1]	$\mu Ci\ cm^{-3}$												
1993	Total Mass	$\mu g\ m^{-3}$												
1994[3]	Total Mass	$\mu g\ m^{-3}$												
1995[4]	Total Mass	$\mu g\ m^{-3}$												
1996	Total Mass	$\mu g\ m^{-3}$												
1997	Total Mass	$\mu g\ m^{-3}$												
1998	Total Mass	$\mu g\ m^{-3}$												
1999	Total Mass	$\mu g\ m^{-3}$												

1. Concentrations reported for ^{234}U, ^{235}U, ^{236}U and ^{238}U.
2. Error in reporting units found for 1987 data. See explanation presented with Table 4.1.2-1.
3. Station 1 inoperable for 1994 and discontinued in 1995.
4. Sampling at all but three stations discontinued.

4.2 Approach for Estimating On Site Air Concentrations

4.2.1 Usability of Air Monitoring Data

Prior to 1983, the various networks of air monitoring stations in and around the ORR were established to monitor for the FP releases. These stations did not measure on site concentrations at Y-12. From 1959 through 1982, the ambient air monitoring station closest to Y-12 was health physics station HP-32 (formerly HP-12), located approximately 0.25 miles from Y-12. In 1983, the first stations dedicated to measuring ambient air concentrations at Y-12 were established.

Ambient air monitoring at Y-12 prior to 1983 is insufficient for estimating environmental doses for several reasons:

- Concentrations of airborne uranium within the Y-12 perimeter were measured from 1983 through 1999. This seventeen-year period represents less than 30% of the operational history of the site. In addition, these data were not collected during the time operations and releases were at their maximum. Therefore these data cannot be used as estimators of historic air concentrations.

- Prior to 1983, the closest health physics station to Y-12 was PAM Station HP-32 (formerly known as HP-12). This station was located at Midway Gate, which is north of the intersection of Bear Creek Road and Lafayette Drive (approximately 0.25 miles from Y-12). Station 40, which replaced station HP-32, began operating in 1983. However, this station is also not located on site.

- Data from these off site stations consisted of total activity, FP activity, gross α and/or gross β. Uranium concentrations were reported as averages across all stations within the PAM network.

- No environmental data of any use to this assessment were found for years preceding 1959. The only reported on site ambient air concentrations prior to 1959 were for gross α and/or gross β.

- An assessment of the measured gross α air concentrations at the health physics stations (HP32 and Station 40) show limited correlation to the uranium release quantities estimated for the period.

Given the distance between the main production areas of Y-12 and the locations of these stations (HP-32 and Station 40), it is unlikely that these stations reflect the level of on site ambient uranium. Consequently, these stations do not present a representative measure of air concentrations at Y-12 and cannot be used to estimate on site doses.

The release of contaminants into the atmosphere at Y-12 occurred primarily as a result of plant fabrication operations. There are reportedly over 700 permitted air pollution sources that are tied into the exhaust ventilation systems of Y-12 (DOE 1989). As reported in the 1988 ASER (DOE 1989), approximately 85 exhausts serve areas where depleted uranium (DU) or enriched uranium (EU) were processed. As discussed in the Oak Ridge Dose Reconstruction (ORDR) Report (ChemRisk 1999), the monitoring of uranium emissions from the various buildings has changed significantly over time. Some of these release points were through monitored stacks; others were through vents and exhaust systems.

Estimating airborne concentrations at locations around Y-12 using traditional dispersion and transport modeling approaches is confounded by a number of factors:

- Numerous release points which include stacks, vents, and other emission sources,

- The characteristics of the release points,

- The relatively short distances between the release points and the on site receptor locations,

- The complexity of the topography of Y-12, including the presence of Pine Ridge to the north, and,

- The density and configuration of buildings at Y-12.

These factors contribute to the complexity of attempting to model the releases using traditional atmospheric dispersion modeling methods. In addition, the approximations necessary to overcome these complexities would increase the level of uncertainty in the estimate of doses.

4.2.2 Empirical Chi/Q (χ/Q) Approach for Estimating Air Concentrations

Due to the limitations of the available data and the complexity of modeling releases as discussed above, an alternative approach was developed for estimating airborne uranium concentrations. An empirical relationship was developed using on site measured air concentrations and estimated uranium release estimates. This approach circumvents the need for air dispersion modeling by providing a direct relationship between uranium air concentrations and uranium releases. In addition,

this approach can be used to estimate air concentrations prior to 1983 by using the empirical Chi/Q value and the estimated uranium releases for earlier years.

Using the available uranium data for 1983 through 1999, the annual average uranium air concentration measured at the Y-12 air monitoring stations is divided by the corresponding estimates for a given year to estimate an annual, station specific, Chi/Q value. The empirical relationship is described by Equation 4.2.2-1 (ChemRisk 1999).

$$Chi/Q\ (m^{-3}) = \frac{Uranium\ Air\ Concentration\ (kg\ m^{-3})}{Uranium\ Mass\ \mathrm{Re}lease\ (kg)} \qquad \text{Equation 4.2.2-1}$$

As discussed in the previous section, there were twelve Y-12 air monitoring stations that operated from 1984 through 1999. Of these 12 stations, four are located within the Y-12 perimeter; the remaining 8 stations are located beyond the fence-line of the facility. These on site locations are Y-12 air monitoring stations 2, 4, 8 and 12. These stations are located within the boundary of the facility and provide coverage of the west (station 8), southeast (station 12), northeast (station 2) and the center (station 4) portions of the facility. Annual Chi/Q values were estimated for these four locations.

4.2.3 Air Concentrations by Location (Chi)

As shown in Table 4.1.2-2, the Y-12 monitoring stations began operations in 1983; however, the type of data reported varied during the 17 years of available information. Uranium air concentrations were reported as either total uranium activity, uranium isotope activity or by total uranium mass. Important factors associated with the available information include:

- Total uranium activity only was reported for 1983 and 1984. To convert the data for these years to isotopic concentrations, the isotopic ratio of the 1985 data for the four uranium isotopes (^{234}U, ^{235}U, ^{236}U, and ^{238}U) was used to partition the measured total uranium activity. This was necessary in order to calculate a mass-based air concentration that is consistent with the other years.

- After 1992, all data were reported in terms of uranium mass ($\mu g\ m^{-3}$). Therefore, data from all previous years was converted to a mass basis for consistency. Conversions were achieved using specific activities for all four isotopes.

- All stations with the exception of stations 4, 5 and 8 were decommissioned after the 1994 monitoring period.

- Station 1 was inoperable in 1994, and Station 12 began operations in 1987, four years after the other eleven stations were brought on line.

- After 1999, responsibility for the remaining stations (4, 5 and 8) was transferred to TDEC and only assessments of gross α and gross β were made from the samples collected.

All measured air concentrations were converted to kg m^{-3} of total uranium so that data dimensions are consistent for all years. Annual average measured air concentrations for the four Y-12 stations selected are tabulated in Tables 4.2.3-1 through 4.2.3-4. Annual average values for gross α, gross β, ^{234}U, ^{235}U, ^{236}U and ^{238}U are included. All reported concentrations for the uranium isotopes are converted to a mass basis (kg m^{-3}) based on specific activities for the four uranium isotopes. For 1983 and 1984, only the total uranium activity was reported ($\mu Ci\ cm^{-3}$). The reported activity was

apportioned to the four uranium isotopes based on the isotopic activity reported for 1985. This assumed that the uranium enrichments for 1983 and 1984 were similar to those reported for 1985.

4.2.4 Release Estimates (Q)

Release estimates for all buildings at Y-12 were previously estimated by Task 6 of the ORDR Project (ChemRisk 1999). These independent estimates were based on a reconstruction of releases from stack monitoring data. Estimates of uranium releases were reconstructed for individual exhaust stacks and vents and were based on information available for individual buildings, uranium processes and from indoor air monitoring data.

The reconstructed estimates cover the period from 1944 through 1988. Estimates from 1989 through 1995 were based on reported releases estimated by DOE. For the purposes of this study, release estimates after 1995 were derived from the ASERs.

1944 – 1988	Release estimates were independently reconstructed as part of the ORDR Project. Estimates were made of total uranium releases (kg and Ci) and isotopic releases ($^{234/235}$U and ^{238}U).	(ChemRisk 1999). Table D-1 of Appendix D of the Task 6 Report (Volume 5)
1989-1995	Release estimates reported in the ORDR were not independently reconstructed. Values were based on estimates reported by DOE.	(ChemRisk 1999). Table D-1 of Appendix D of the Task 6 Report (Volume 5)
1996-2001	Independent sources were not available. Estimates are those reported in the ORR – ASER for Y-12.	(DOE 2000, DOE 2001, DOE 2002)

A compilation of these release estimates is presented in Table 4.2.4-1. A combined $^{234/235}$U release estimate was reconstructed as part of the ORDR Project (ChemRisk 1999). This approach was selected by the Dose Reconstruction Team to generate a conservative estimate of off site dose. Since these release estimates cannot be distinguished without further reconstruction, the air concentrations used in this assessment are in terms of a combined activity ($^{234/235}$U). Figure 4.2.4-1 shows the distribution of $^{234/235}$U and ^{238}U with time. The highest reconstructed $^{234/235}$U release was in 1958 (17.4 Ci); the highest ^{238}U release was in 1959 (2.0 Ci).

4.2.5 Correlation of Air Concentrations with Releases

To validate the Chi/Q approach, the uranium air concentrations measured at each of the four Y-12 stations of interest (2, 4, 8 and 12) were plotted against the reported uranium release estimates to determine if a valid correlation exists. A correlation coefficient (R^2) was estimated from the plotted data. Figures 4.2.5-1 through 4.2.5-4 show the relationship of measured air concentrations with uranium release estimates. Values of the correlation coefficient (R^2) are included.

The R^2 values show an acceptable correlation between the measured air concentrations and the release estimates indicating that the empirical Chi/Q approach is valid. The only exception is station 12. The poor correlation is most likely due to the fact that there are only 8 data points for this station. This station did not start collecting samples until 1987, which is four years after the other stations were brought online. In addition, the range of uranium release estimates for the years when this station was operational, is significantly lower than for previous years.

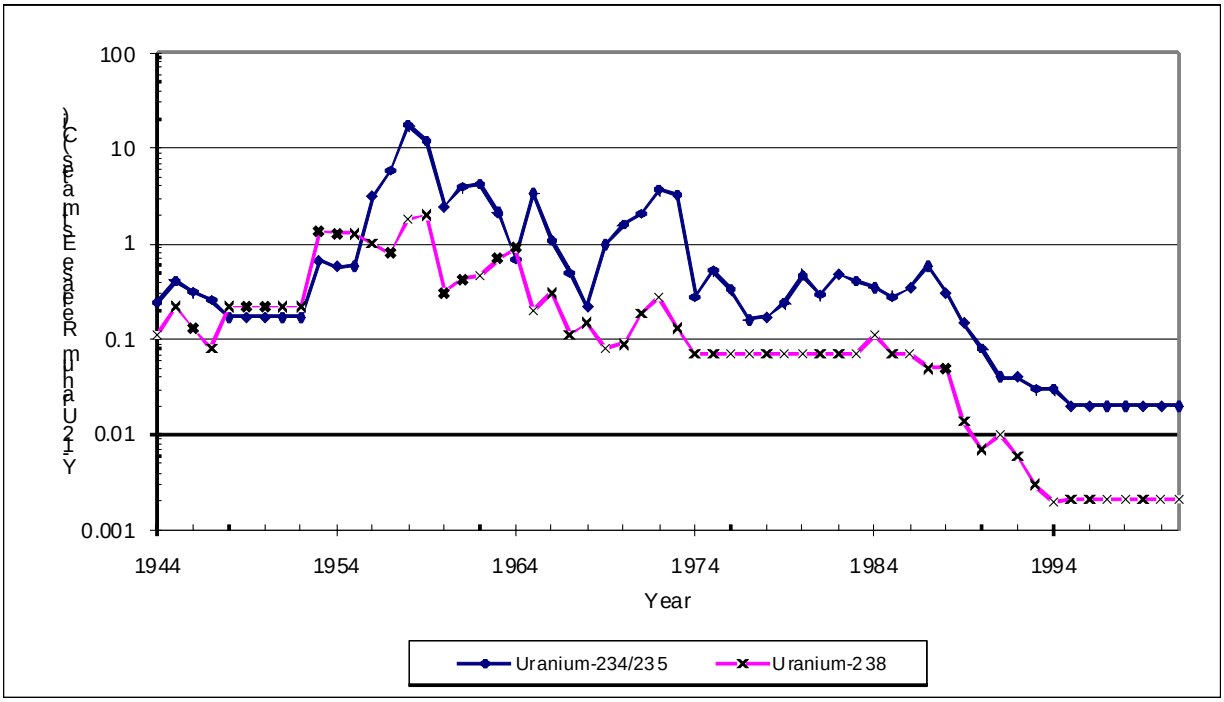

Figure 4.2.4-1. Distribution of release estimates for the Y-12 facility. Release estimates for 1944 through 1995 were independently reconstructed by the Oak Ridge Dose Reconstruction Project (ChemRisk 1999).

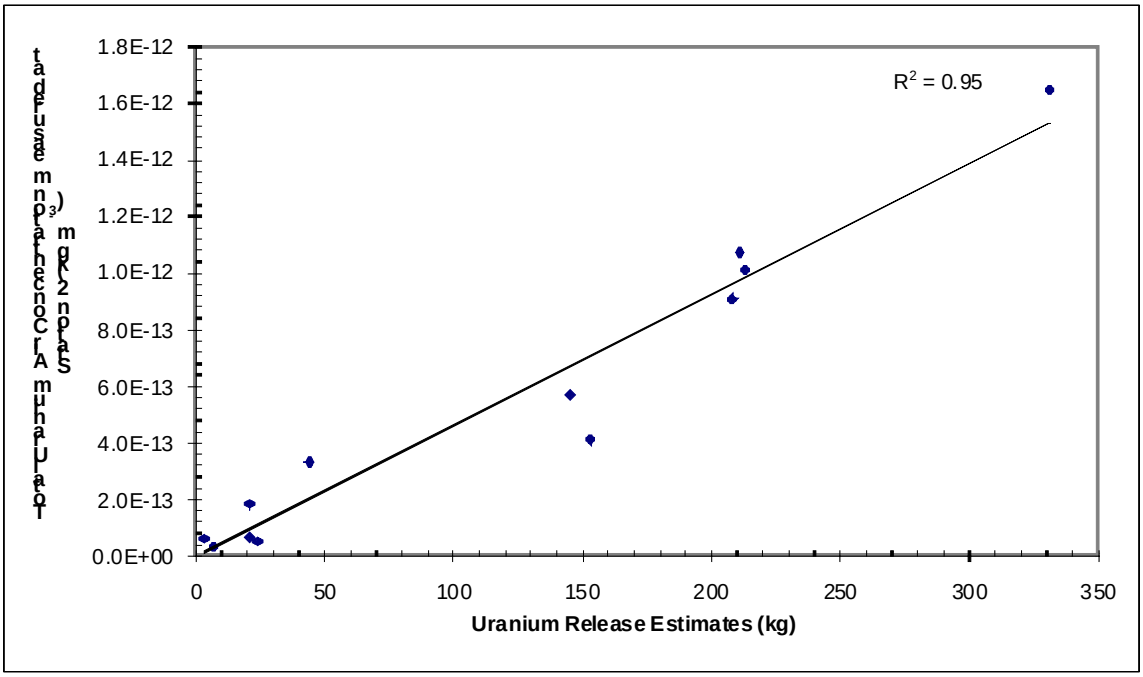

Figure 4.2.5-1. Plot of annual total uranium air concentration measured at Station 2 verses estimated uranium releases. Correlation coefficient $R^2 = 0.95$.

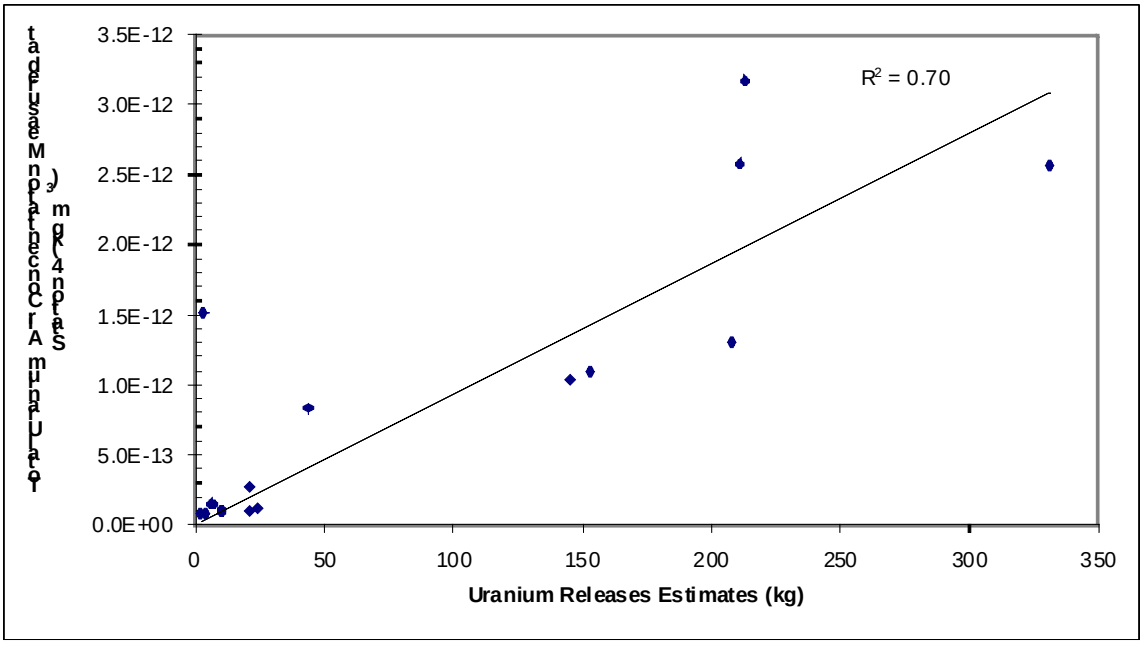

Figure 4.2.5-2. Plot of annual total uranium air concentration measured at Station 4 verses estimated uranium releases. Correlation coefficient $R^2 = 0.70$.

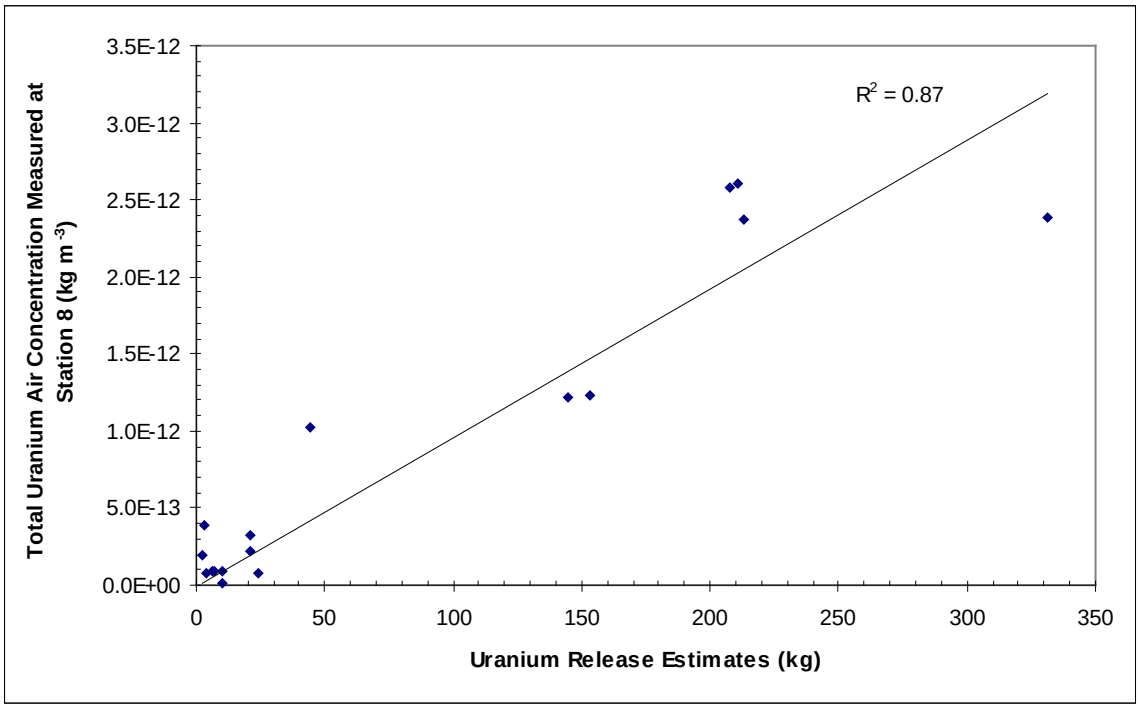

Figure 4.2.5-3. Plot of annual total uranium air concentration measured at Station 8 verses estimated uranium releases. Correlation coefficient $R^2 = 0.87$.

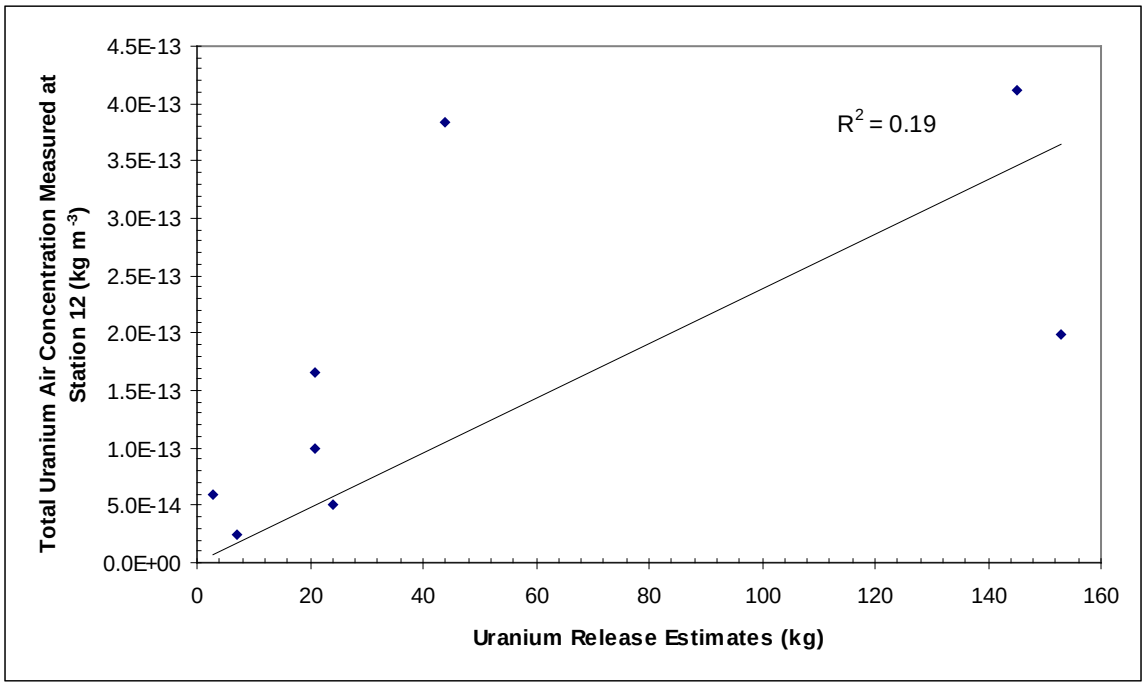

Figure 4.2.5-4. Plot of annual total uranium air concentration measured at Station 12 verses estimated uranium releases. Correlation coefficient $R^2 = 0.19$.

Generally, the correlation of uranium air concentrations with uranium releases displays a strong relationship indicating that the stations appropriately represent an adequate measure of ambient uranium concentrations as result of uranium releases from Y-12 operations.

4.2.6 Estimating Chi/Q for Y-12 Stations

The empirical Chi/Q relationship, described in Equation 4.2.2-1 above, uses the average uranium air concentration at each station (Chi) from Tables 4.2.3-1 to 4.2.3-4, and the release estimates (Q) in Table 4.2.4-1. Values of Chi/Q are calculated for each of the four locations (Stations 2, 4, 8 and 12) by dividing the average annual air concentration estimated in kg m^{-3} by the release estimates for that year in kg. Annual Chi/Q values were calculated for each station for each year for which air concentrations were available.

Station 2	Air concentrations were reported for 1983 through 1994. This station was decommissioned after the 1994 sampling rounds.	12 Chi/Q values
Station 4 Station 8	Air concentrations were reported for 1983 through 1999. Responsibility for this station was transferred to TDEC. Only gross α and gross β measurements after 1999.	17 Chi/Q values per station.
Station 12	Air concentrations were reported for 1987 through 1994. This station was added to the network in 1987, and was decommissioned after the 1994 sampling rounds.	8 Chi/Q values

Table 4.2.3-1. Annual average air concentrations and estimated Chi/Q values for Y-12 Station 2.

Year	Gross α (μCi cm^{-3})	Gross β (μCi cm^{-3})	^{234}U (μCi cm^{-3})	^{235}U (μCi cm^{-3})	^{236}U (μCi cm^{-3})	^{238}U (μCi cm^{-3})	Total Uranium (mass or activity)	Conversion to Mass[3] (kg m^{-3})	Y-12 Release Estimates (kg)	CHI/Q (m^{-3})
1983[1]	-	-	3.90E-15	1.61E-16	1.78E-16	2.80E-16	4.52E-15 (μCi cm^{-3})	9.08E-13	208	4.37E-15
1984[1]	-	-	7.08E-15	2.92E-16	3.23E-16	5.08E-16	8.20E-15 (μCi cm^{-3})	1.65E-12	331	4.98E-15
1985	8.20E-15	2.00E-14	4.60E-15	1.90E-16	2.10E-16	3.30E-16	-	1.07E-12	211	5.08E-15
1986	6.00E-15	2.80E-14	3.80E-15	1.30E-16	1.00E-16	3.20E-16	-	1.01E-12	213	4.75E-15
1987	3.32E-15	1.65E-14	1.30E-15	5.00E-17	8.20E-17	1.30E-16	-	4.10E-13	153	2.68E-15
1988	3.71E-15	2.09E-14	1.55E-15	6.90E-17	8.90E-17	1.81E-16	-	5.71E-13	145	3.94E-15
1989	2.70E-15	1.90E-14	1.28E-15	7.00E-17	2.60E-17	1.01E-16	-	3.33E-13	44	7.56E-15
1990	1.31E-15	1.03E-14	4.00E-16	2.49E-17	2.25E-17	5.73E-17	-	1.82E-13	21	8.67E-15
1991	5.68E-16	6.88E-15	2.00E-16	4.20E-18	2.90E-18	2.14E-17	-	6.55E-14	21	3.12E-15
1992	1.26E-16	4.52E-15	6.14E-17	4.00E-18	2.40E-18	1.05E-17	-	3.31E-14	7	4.72E-15
1993[2]	-	-	-	-	-	-	6.00E-05 (μg m^{-3})	6.00E-14	3	2.00E-14
1994[2]	-	-	-	-	-	-	5.00E-05 (μg m^{-3})	5.00E-14	24	2.08E-15
1995[2]	-	-	-	-	-	-	-	-	-	-
1996[2]	-	-	-	-	-	-	-	-	-	-
1997[2]	-	-	-	-	-	-	-	-	-	-
1998[2]	-	-	-	-	-	-	-	-	-	-
1999[2]	-	-	-	-	-	-	-	-	-	-

Station 2 Chi/Q (m^{-3})	
Minimum	2.08E-15
Maximum	2.00E-14
Count	12
Geometric Mean (GM)	4.96E-15
Geometric Standard Deviation (GSD)	1.81
50th Percentile (Lognormal)	4.96E-15
95th Percentile (Lognormal)	1.31E-14

NOTE
1 1983 and 1984 data were reported as total uranium activity only. ^{234}U, ^{235}U, ^{236}U and ^{238}U air concentrations were calculated based on isotopic activity ratios from 1985 data.
2 Reported annual average concentration in μg m^{-3}.
3 Conversion to mass using specific activities for ^{234}U, ^{235}U, ^{236}U and ^{238}U.

Table 4.2.3-2. Annual average air concentrations and estimated Chi/Q values for Y-12 Station 4.

Year	Gross α (μCi cm^{-3})	Gross β (μCi cm^{-3})	^{234}U (μCi cm^{-3})	^{235}U (μCi cm^{-3})	^{236}U (μCi cm^{-3})	^{238}U (μCi cm^{-3})	Total Uranium (mass or activity)	Conversion to Mass[3] (kg m^{-3})	Y-12 Release Estimates (kg)	CHI/Q (m^{-3})
1983[1]	-	-	9.61E-15	4.40E-16	2.73E-16	3.69E-16	1.07E-14 (μCi cm^{-3})	1.30E-12	208	6.27E-15
1984[1]	-	-	1.89E-14	8.64E-16	5.36E-16	7.25E-16	2.10E-14 (μCi cm^{-3})	2.56E-12	331	7.74E-15
1985	2.60E-14	3.20E-14	1.90E-14	8.70E-16	5.40E-16	7.30E-16	-	2.58E-12	211	1.22E-14
1986	2.27E-14	5.12E-14	1.57E-14	6.70E-16	7.00E-16	9.60E-16	-	3.17E-12	213	1.49E-14
1987	7.25E-15	1.97E-14	4.10E-15	1.80E-16	2.10E-16	3.40E-16	-	1.10E-12	153	7.17E-15
1988	5.69E-15	2.25E-14	4.39E-15	1.00E-16	1.15E-16	3.31E-16	-	1.03E-12	145	7.11E-15
1989	3.67E-15	2.08E-14	2.40E-15	6.90E-17	4.00E-17	2.69E-16	-	8.31E-13	44	1.89E-14
1990	1.88E-15	1.10E-14	1.47E-15	4.83E-17	4.61E-17	8.35E-17	-	2.71E-13	21	1.29E-14
1991	6.73E-16	5.64E-15	5.82E-16	1.55E-17	9.00E-18	2.89E-17	-	9.32E-14	21	4.44E-15
1992	5.21E-16	4.10E-15	2.23E-16	1.04E-17	3.70E-18	4.69E-17	-	1.44E-13	7	2.06E-14
1993[2]	-	-	-	-	-	-	1.51E-03 (μg m^{-3})	1.51E-12	3	5.03E-13
1994[2]	-	-	-	-	-	-	1.20E-04 (μg m^{-3})	1.20E-13	24	5.00E-15
1995[2]	-	-	-	-	-	-	8.00E-05 (μg m^{-3})	8.00E-14	2	4.00E-14
1996[2]	-	-	-	-	-	-	9.00E-05 (μg m^{-3})	9.00E-14	10	9.00E-15
1997[2]	-	-	-	-	-	-	1.50E-04 (μg m^{-3})	1.50E-13	6	2.50E-14
1998[2]	-	-	-	-	-	-	1.10E-04 (μg m^{-3})	1.10E-13	10	1.10E-14
1999[2]	-	-	-	-	-	-	8.00E-05 (μg m^{-3})	8.00E-14	4	2.00E-14

Station 4 Chi/Q (m^{-3})	
Minimum	4.44E-15
Maximum	5.03E-13
Count	17
Geometric Mean (GM)	1.44E-14
Geometric Standard Deviation (GSD)	3.00
50th Percentile (Lognormal)	1.44E-14
95th Percentile (Lognormal)	8.73E-14

NOTE
1 1983 and 1984 data were reported as total uranium activity only. ^{234}U, ^{235}U, ^{236}U and ^{238}U air concentrations were calculated based on isotopic activity ratios from 1985 data.
2 Reported annual average concentration in μg m^{-3}.
3 Conversion to mass using specific activities for ^{234}U, ^{235}U, ^{236}U and ^{238}U.

Table 4.2.3-3. Annual average air concentrations and estimated Chi/Q values for Y-12 Station 8.

Year	Gross α (μCi cm^{-3})	Gross β (μCi cm^{-3})	^{234}U (μCi cm^{-3})	^{235}U (μCi cm^{-3})	^{236}U (μCi cm^{-3})	^{238}U (μCi cm^{-3})	Total Uranium (mass or activity)	Conversion to Mass[3] (kg m^{-3})	Y-12 Release Estimates (kg)	CHI/Q (m^{-3})
1983[1]	-	-	7.20E-15	3.06E-16	2.27E-16	8.19E-16	8.55E-15 (μCi cm^{-3})	2.58E-12	208	1.24E-14
1984[1]	-	-	6.65E-15	2.82E-16	2.10E-16	7.56E-16	7.90E-15 (μCi cm^{-3})	2.38E-12	331	7.19E-15
1985	1.30E-14	2.20E-14	7.30E-15	3.10E-16	2.30E-16	8.30E-16	-	2.61E-12	211	1.24E-14
1986	1.22E-14	3.10E-14	7.20E-15	3.10E-16	1.70E-16	7.50E-16	-	2.37E-12	213	1.11E-14
1987	8.30E-15	1.90E-14	6.30E-15	2.90E-16	2.00E-16	3.70E-16	-	1.24E-12	153	8.08E-15
1988	4.99E-15	2.46E-14	2.21E-15	1.37E-16	1.68E-16	3.87E-16	-	1.21E-12	145	8.38E-15
1989	4.14E-15	2.16E-14	1.68E-15	1.37E-16	6.70E-17	3.23E-16	-	1.02E-12	44	2.33E-14
1990	1.69E-15	1.18E-14	4.06E-16	1.99E-17	7.90E-18	1.04E-16	-	3.18E-13	21	1.51E-14
1991	5.46E-16	6.51E-15	3.20E-16	5.19E-17	3.60E-18	6.81E-17	-	2.26E-13	21	1.08E-14
1992	1.88E-16	4.55E-15	1.90E-16	2.44E-17	5.10E-18	2.46E-17	-	8.44E-14	7	1.21E-14
1993[2]	-	-	-	-	-	-	3.90E-04 (μg m^{-3})	3.90E-13	3	1.30E-13
1994[2]	-	-	-	-	-	-	8.00E-05 (μg m^{-3})	8.00E-14	24	3.33E-15
1995[2]	-	-	-	-	-	-	2.00E-04 (μg m^{-3})	2.00E-13	2	1.00E-13
1996[2]	-	-	-	-	-	-	9.00E-05 (μg m^{-3})	9.00E-14	10	9.00E-15
1997[2]	-	-	-	-	-	-	9.05E-05 (μg m^{-3})	9.05E-14	6	1.51E-14
1998[2]	-	-	-	-	-	-	1.10E-05 (μg m^{-3})	1.10E-14	10	1.10E-15
1999[2]	-	-	-	-	-	-	8.00E-05 (μg m^{-3})	8.00E-14	4	2.00E-14

Station 8 Chi/Q (m^{-3})	
Minimum	1.10E-15
Maximum	1.30E-13
Count	17
Geometric Mean (GM)	1.26E-14
Geometric Standard Deviation (GSD)	2.97
50th Percentile (Lognormal)	1.26E-14
95th Percentile (Lognormal)	7.53E-14

NOTE

1 1983 and 1984 data were reported as total uranium activity only. ^{234}U, ^{235}U, ^{236}U and ^{238}U air concentrations were calculated based on isotopic activity ratios from 1985 data.

2 Reported annual average concentration in μg m^{-3}.

3 Conversion to mass using specific activities for ^{234}U, ^{235}U, ^{236}U and ^{238}U.

Table 4.2.3-4. Annual average air concentrations and estimated Chi/Q values for Y-12 Station 12.

Year	Gross α (μCi cm^{-3})	Gross β (μCi cm^{-3})	^{234}U (μCi cm^{-3})	^{235}U (μCi cm^{-3})	^{236}U (μCi cm^{-3})	^{238}U (μCi cm^{-3})	Total Uranium (mass or activity)	Conversion to Mass[3] (kg m^{-3})	Y-12 Release Estimates (kg)	CHI/Q (m^{-3})
1983[1]	-	-	-	-	-	-	-	-	-	-
1984[1]	-	-	-	-	-	-	-	-	-	-
1985[1]	-	-	-	-	-	-	-	-	-	-
1986[1]	-	-	-	-	-	-	-	-	-	-
1987	2.78E-15	1.21E-14	5.20E-16	6.10E-17	7.00E-17	5.70E-17	-	1.99E-13	153	1.30E-15
1988	4.06E-15	2.31E-14	1.01E-15	7.40E-17	7.20E-17	1.27E-16	-	4.12E-13	145	2.84E-15
1989	3.10E-15	2.08E-14	1.32E-15	8.80E-17	6.90E-17	1.15E-16	-	3.83E-13	44	8.71E-15
1990	1.61E-15	1.23E-14	3.21E-16	1.48E-17	8.90E-18	5.35E-17	-	1.66E-13	21	7.90E-15
1991	4.93E-16	6.84E-15	1.34E-16	3.46E-17	9.30E-18	2.79E-17	-	9.90E-14	21	4.71E-15
1992	2.14E-16	5.41E-15	5.62E-17	2.50E-18	1.50E-18	8.10E-18	-	2.52E-14	7	3.60E-15
1993[2]	-	-	-	-	-	-	6.00E-05 (μg m^{-3})	6.00E-14	3	2.00E-14
1994[2]	-	-	-	-	-	-	5.00E-05 (μg m^{-3})	5.00E-14	24	2.08E-15
1995[2]	-	-	-	-	-	-	-	-	-	-
1996[2]	-	-	-	-	-	-	-	-	-	-
1997[2]	-	-	-	-	-	-	-	-	-	-
1998[2]	-	-	-	-	-	-	-	-	-	-
1999[2]	-	-	-	-	-	-	-	-	-	-

Station 12 Chi/Q (m^{-3})	
Minimum	1.30E-15
Maximum	2.00E-14
Count	8
Geometric Mean (GM)	4.54E-15
Geometric Standard Deviation (GSD)	2.40
50th Percentile (Lognormal)	4.54E-15
95th Percentile (Lognormal)	1.92E-14

NOTE
1 Station was not operational and was brought on line in 1987
2 Reported annual average concentration in μg m^{-3}.
3 Conversion to mass using specific activities for ^{234}U, ^{235}U, ^{236}U and ^{238}U.

Table 4.2.4-1. Compiled annual uranium release estimates (Q).

Year	Uranium (kg)	Uranium (Ci)	$^{234/235}U$ (kg)	^{238}U (kg)	$^{234/235}U$ (Ci)	^{238}U (Ci)	Source
1944	311	0.35	5	307	0.24	0.11	ChemRisk 1999 (Table D-1)
1945	665	0.63	8	657	0.41	0.22	ChemRisk 1999 (Table D-1)
1946	385	0.44	6	379	0.31	0.13	ChemRisk 1999 (Table D-1)
1947	250	0.34	5	245	0.26	0.08	ChemRisk 1999 (Table D-1)
1948	650	0.39	3	647	0.17	0.22	ChemRisk 1999 (Table D-1)
1949	650	0.39	3	647	0.17	0.22	ChemRisk 1999 (Table D-1)
1950	650	0.39	3	647	0.17	0.22	ChemRisk 1999 (Table D-1)
1951	650	0.39	3	647	0.17	0.22	ChemRisk 1999 (Table D-1)
1952	650	0.39	3	647	0.17	0.22	ChemRisk 1999 (Table D-1)
1953	4015	2.04	12	4002	0.67	1.36	ChemRisk 1999 (Table D-1)
1954	3765	1.86	11	3754	0.58	1.28	ChemRisk 1999 (Table D-1)
1955	3765	1.87	11	3754	0.59	1.28	ChemRisk 1999 (Table D-1)
1956	3037	4.2	41	2995	3.2	1	ChemRisk 1999 (Table D-1)
1957	2309	6.6	72	2236	5.8	0.8	ChemRisk 1999 (Table D-1)
1958	5657	19.2	214	5443	17.4	1.8	ChemRisk 1999 (Table D-1)
1959	6149	13.9	148	6001	11.9	2	ChemRisk 1999 (Table D-1)
1960	934	2.73	28	906	2.43	0.31	ChemRisk 1999 (Table D-1)
1961	1321	4.33	45	1276	3.9	0.43	ChemRisk 1999 (Table D-1)
1962	1390	4.67	49	1341	4.21	0.46	ChemRisk 1999 (Table D-1)
1963	2091	2.83	28	2063	2.1	0.7	ChemRisk 1999 (Table D-1)
1964	2672	1.58	10	2662	0.68	0.91	ChemRisk 1999 (Table D-1)
1965	635	3.61	42	593	3.41	0.2	ChemRisk 1999 (Table D-1)
1966	921	1.4	14	907	1.09	0.31	ChemRisk 1999 (Table D-1)
1967	339	0.62	6	332	0.5	0.11	ChemRisk 1999 (Table D-1)
1968	439	0.37	3	436	0.22	0.15	ChemRisk 1999 (Table D-1)
1969	247	1.05	12	235	0.97	0.08	ChemRisk 1999 (Table D-1)
1970	295	1.68	19	276	1.59	0.09	ChemRisk 1999 (Table D-1)
1971	575	2.26	25	549	2.07	0.19	ChemRisk 1999 (Table D-1)
1972	874	3.95	47	827	3.66	0.28	ChemRisk 1999 (Table D-1)
1973	410	3.36	39	371	3.23	0.13	ChemRisk 1999 (Table D-1)
1974	208	0.35	4	204	0.28	0.07	ChemRisk 1999 (Table D-1)
1975	210	0.59	7	203	0.52	0.07	ChemRisk 1999 (Table D-1)
1976	208	0.4	4	204	0.33	0.07	ChemRisk 1999 (Table D-1)
1977	206	0.23	2	204	0.16	0.07	ChemRisk 1999 (Table D-1)
1978	206	0.24	2	204	0.17	0.07	ChemRisk 1999 (Table D-1)
1979	207	0.31	3	204	0.24	0.07	ChemRisk 1999 (Table D-1)
1980	222	0.54	6	216	0.47	0.07	ChemRisk 1999 (Table D-1)
1981	207	0.36	4	203	0.29	0.07	ChemRisk 1999 (Table D-1)
1982	207	0.55	6	201	0.48	0.07	ChemRisk 1999 (Table D-1)
1983	208	0.48	5	203	0.41	0.07	ChemRisk 1999 (Table D-1)
1984	331	0.46	5	326	0.35	0.11	ChemRisk 1999 (Table D-1)
1985	211	0.35	4	207	0.28	0.07	ChemRisk 1999 (Table D-1)
1986	213	0.42	5	208	0.35	0.07	ChemRisk 1999 (Table D-1)
1987	153	0.64	7	146	0.59	0.05	ChemRisk 1999 (Table D-1)
1988	145	0.35	4	142	0.3	0.05	ChemRisk 1999 (Table D-1)
1989	44	0.15	7	37	0.15	0.014	ChemRisk 1999 (Table D-1)
1990	21	0.8	6	15	0.08	0.007	ChemRisk 1999 (Table D-1)
1991	21	0.05	1	20	0.04	0.01	ChemRisk 1999 (Table D-1)
1992	7	0.04	1	7	0.04	0.006	ChemRisk 1999 (Table D-1)
1993	3	0.03	0.4	3	0.03	0.003	ChemRisk 1999 (Table D-1)

Table 4.2.4-1. (Continued)

Year	Uranium (kg)	Uranium (Ci)	$^{234/235}$U (kg)	^{238}U (kg)	$^{234/235}$U (Ci)	^{238}U (Ci)	Source
1994	24	0.04	0.4	24	0.03	0.002	ChemRisk 1999 (Table D-1)
1995	2	0.02	0.3	2	0.02	0.0021	ChemRisk 1999 (Table D-1)
1996	9.7	-	-	-	-	-	DOE 2000, page 6-2
1997	6	-	-	-	-	-	DOE 2000, page 6-2
1998	10	-	-	-	-	-	DOE 2000, page 6-2
1999	3.9	-	-	-	-	-	DOE 2000, page 6-2
2000	2.2	-	-	-	-	-	DOE 2001, page 6-5
2001	3.4	-	-		-	-	DOE 2002, page 6-5

Given the limited number of data points, a definitive characterization of the underlying distribution was not possible with any statistical certainty. However, the distribution of Chi/Q values exhibit characteristics of a lognormal distribution with a defined tail of higher values. Estimations of central tendency were made assuming the distribution of the Chi/Q values for each station was lognormal and estimates of the geometric mean (GM) and geometric standard deviation (GSD) are included in Tables 4.2.3-1 to 4.2.3-4. Estimates of the 50th and 95th percentile value of the Chi/Q value for each station were generated assuming the underlying distributions were lognormal. The percentiles were calculated using Equation 4.2.6-1, as described by Gilbert (1987).

$$\hat{x}_p = \exp(\bar{y} + Z_p\, s_y) \qquad \text{Equation 4.2.6-1}$$

Where:

$\hat{x}_p$ = pth percentile of data set assuming distribution is lognormal,

$\bar{y}$ = arithmetic mean of the log transformed values of Chi/Q,

Z_p = pth percentile of a standard normal distribution,

s_y = standard deviation of the log transformed values of Chi/Q.

4.3 Estimation of Air Concentrations

Uranium air concentrations and annual intakes were calculated for the four on site locations at Y-12. These locations are represented by Y-12 air monitoring stations 2, 4, 8 and 12. These stations are located within the boundary of the facility and provide coverage of the west (station 8), southeast (station 12), northeast (station 2) and the center (station 4) portions of the facility (Figure 4.3-1).

Utilizing the Chi/Q estimates for each station, and the annual Y-12 airborne release estimates in Table 4.2.4-1, annual uranium air concentrations (Ci m^{-3}) at the four locations were obtained by multiplying the Chi/Q value for each station (m^{-3}) by the uranium release estimate (Ci) for $^{234/235}$U and ^{238}U. Annual uranium air concentration was calculated for each of the four specified locations for all years from 1944 to 2002. The air concentrations were estimated using the 50th and 95th percentile values for the Chi/Q values for each station. Even though measured uranium concentrations in air were available for 1983 through 1999, the air concentrations generated by the Chi/Q approach were used to estimate intakes. This approach was selected to maintain consistency with the preceding years.

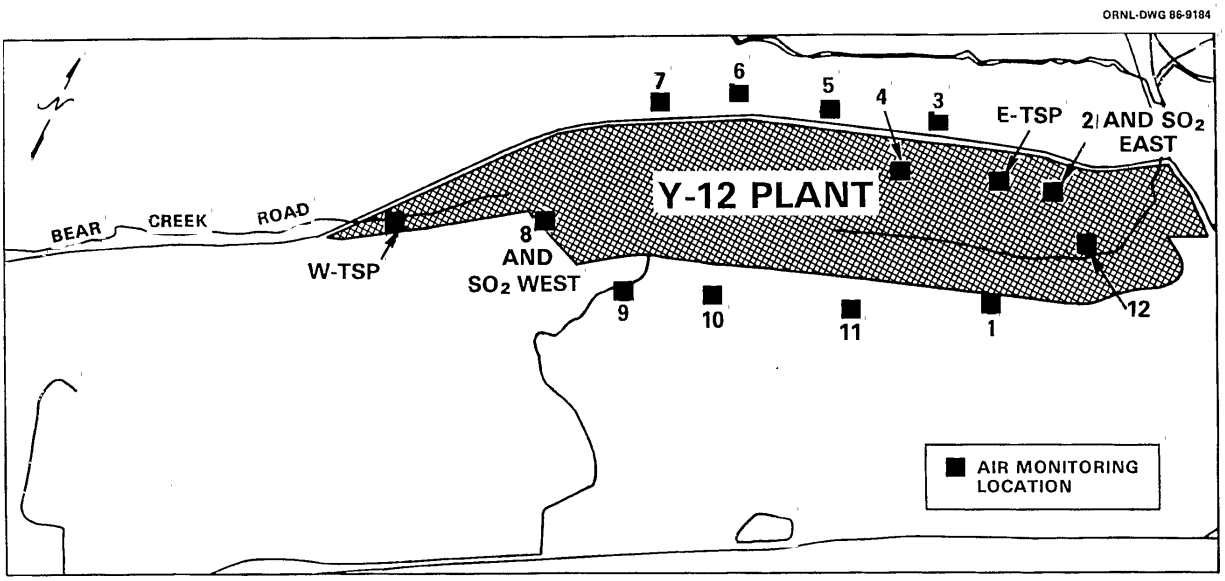

Figure 4.3-1. Locations of Y-12 perimeter air monitoring stations (DOE 1990).

The ORDR Project estimated releases from 1944 to 1995. Thus, this source cannot be used to estimate air concentrations from 1996 to 2002. The release estimates in Table 4.2.4-1 show a definite downward trend for the years preceding 1995 (Figure 4.3-2). Thus, it is conservative to assume that the air concentrations reported from 1996 to 2002 are equal to the concentrations reported for 1995.

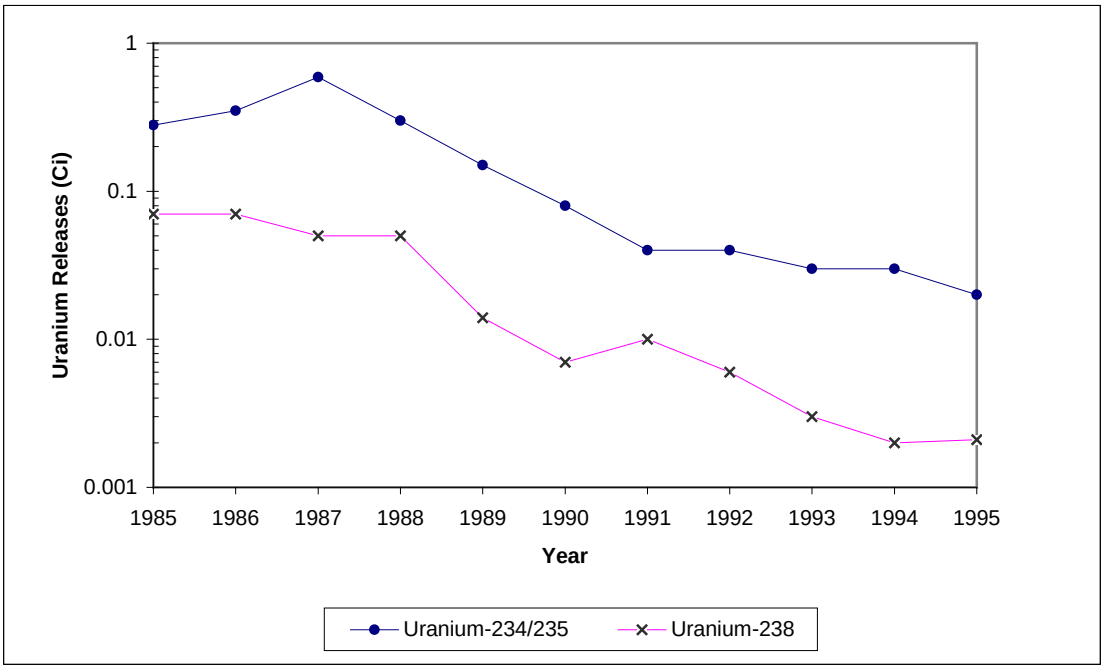

Figure 4.3-2. Distribution of $^{234/235}$U and ^{238}U release estimates for the years 1985 through 1995. The trend shows a definite downward trend for the years preceding 1995.

Air concentrations and intakes for the four on site locations are presented in Tables D-1 to D-4 in Attachment D. The uranium air concentrations are based on the 50th and 95th percentile value of the lognormally distributed Chi/Q.

In addition, a site wide average air concentration and intake were estimated based on the annual concentrations from stations 2, 4, 8 and 12. These values are reported in Table D-5 in Attachment D. The maximum air concentrations for the uranium isotopes from all four locations were also compiled. The 50th and 95th percentiles of both air concentration and intake are presented in Table D-6 in Attachment D. Note that the percentiles are based on the statistics of the Chi/Q estimation and not on the data from the four stations.

Estimates of intake assume 2,000 h y^{-1} exposure. An inhalation rate of 1.2 m^3 h^{-1} generates an annual intake off 2,400 m^3 y^{-1}.

For estimating air concentrations and intakes for the four specific on site locations at Y-12 by selecting the location that closely represents the exposure location.	Tables D-1 through D-4	Average and 95th Percentile air concentration and intake for $^{234/235}$U and ^{238}U
For estimating Y-12 average air concentrations and intakes based on an annual average from all four on site locations.	Table D-5	
Maximum air concentrations and intakes based on the highest Chi/Q value (represented by Station 4)	Table D-6	

4.4 Occupational External Dose

There are two potential sources of external exposures received by workers at the Y-12 facility:

1. Exposures from the deposition of radionuclides released as a consequence of facility operations,

2. Exposures received from radiation levels emanating from buildings and storage areas.

4.4.1 Data Availability

Environmental monitoring of external exposures was performed at health physics monitoring stations and is reported in the Annual Site Environmental Reports. Prior to 1983, the only health physics monitoring stations for Y-12 were located off site, and consequently were not useful for estimating worker exposures. No measurements of external exposures were reported for the twelve on site stations at Y-12, which began operations in 1983. With the exception of the limited data from environmental monitoring reports, there are two major characterizations of external exposures that have been performed for Y-12. A series of aerial radiological surveys was performed in 1973-1974, 1980, 1989 and 1992 for the ORR that included Y-12. These surveys consisted of a reservation wide, high level survey and low-level facility specific surveys. The second major characterization was performed from 1985 to 1987 and involved an outdoor radiological and chemical scoping survey of the 800+ acres occupied by the Y-12 facility. This survey included both radiological and chemical assessments and included measurements of both gamma ray exposure rates and the collection of

surface soil samples. The purpose of the scoping survey was to locate and prioritize areas of concern from both a worker health and safety and from an environmental assessment standpoint. The approach, results and relative merits of both efforts are discussed below.

4.4.2 Range of Exposures from Aerial Surveys

Aerial Radiological Survey 1973-1974 (EG&G 1976)
The survey consisted of airborne measurements of both man-made and natural radioisotopes in and around the three DOE facilities as well as surrounding areas that are not part of the ORR. Results were presented as radiation intensity isopleths that were superimposed onto aerial photographs. Aerial measurements were related to exposure levels at one meter above ground. The natural background levels were estimated to vary between 4 to 6 $\mu R\ h^{-1}$ for Y-12. This does not include an exposure rate of 3.8 $\mu R\ h^{-1}$ from cosmic radiation.

Radiation levels at Y-12 can be separated into five distinct areas of higher than background exposures. The highest exposure range of 50-100 $\mu R\ h^{-1}$ was centered around a waste disposal pond located at the west end of the facility. Higher areas were inferred from the ^{208}Tl peak (attributable to thorium). These exposures were attributed to a coal pile. Additional ^{208}Tl isopleths were attributed to thorium storage areas producing maximum exposure values ranging from 13 to 25 $\mu R\ h^{-1}$. Tons of ^{238}U stored at the west end of Y-12 produced maximum levels ranging from 50 to 100 $\mu R\ h^{-1}$. Exposure rates in these five areas range from 1.5 to 100 $\mu R\ h^{-1}$ over approximately 50% of the site.

Other sources included collimated sources and x-ray machines located in buildings. Multiple flyovers indicate that these sources were not in constant operation.

Aerial Radiological Survey 1980 (EG&G 1984)
The focus of the second aerial survey was to identify specific radiological sources including ^{60}Co, ^{234m}Pa and ^{137}Cs. Isopleths for the vicinity of the Y-12 area show three major areas of elevated exposure rates. All are located towards the west end of the facility with the highest isopleths relating to an exposure rate of 100 to 200 $\mu R\ h^{-1}$. The resolution of the isopleths prevents a determination of exact location of these sources of higher exposure. These areas of higher exposure are limited to the west side of the facility. The remainder of Y-12 is within the 11.8 to 20 $\mu R\ h^{-1}$ exposure range.

Aerial Radiological Survey 1989 (EG&G 1992)
The exposure rates for the Y-12 facility show a reduction in the number of areas of elevated readings as compared to the 1980 survey. The highest exposures are still localized over a small area at the west end of the site. The net spectra are dominated by the ^{234m}Pa photopeak indicating the presence of DU. Maximum exposures ranged from 35 to 80 $\mu R\ hr^{-1}$ for this area. Two smaller areas in the 14 to 35 $\mu R\ h^{-1}$ range were noted in the center portion of the site. The spectra for one of these areas are related to the ^{235}U and appear to be centered over the production areas. This photopeak was not observed during the previous flyover. The net spectra for the other area are indicative of Th.

Aerial Radiological Survey 1992 (EG&G 1993)
The 1992 survey identified six areas within the Y-12 complex with elevated exposure rates. Three of these areas show evidence of ^{234m}Pa, indicating that the source is DU. The highest area is located toward the west end of the site with the maximum isopleth range of 20 to 50 $\mu R\ h^{-1}$. This area of concern, attributed to DU, is likely to be the same source area (waste disposal area) as identified in

previous surveys. The maximum isopleths for the other 5 areas range from 13 to 20 μR h^{-1}. The spectra for two of these areas show the characteristic photopeak for ^{235}U and are located over areas that are either associated with production or material storage. The remainder of the site is encompassed by isopleths ranging from 8 to 13 μR h^{-1}.

4.4.3 Results of 1987 Scoping Survey

An outdoor radiological and chemical scoping survey was conducted at Y-12 between September 1985 and May 1987 (Foley and Carrier 1990). The survey included the approximately 800 acres of the plant, as well as adjacent areas where emission depositions likely occurred. The purpose of the survey was to locate and prioritize areas of concern from both a worker health and safety and from an environmental assessment standpoint. The survey included measurements of both gamma ray exposure rates and collection of surface soil samples. The measurement of gamma ray exposure rates was made by direct measurements at grid locations and by scans of areas within grid blocks.

The entire site was initially partitioned into 22 priority areas. Five areas were later sub-divided to form additional survey areas for a total of 27 priority areas. The priority areas were established by Y-12 Management to encompass logical units of operation and to maintain manageable survey grids. Each area was further divided into grid blocks according to the Y-12 master grid plan. Each block varied in size according to the degree of contamination expected. Grid blocks with closely spaced buildings were sized as 100'x100'; open areas were divided into 200'x200' grid blocks.

Exposure measurements for each grid block comprised of a range of exposure levels and direct readings at specific grid intersections. Each grid block was thoroughly scanned with a portable gamma scintillation meter (1¼" x 1½" NaI probe). The scan produced a range of exposure levels for each grid block. Direct exposure measurements were also made at each grid line intersection. All gamma measurements were made at ground surface.

The results of the scans and direct measurements were tabulated for each of the 27 priority areas. Ranges of measurements were provided in the report, but no further analysis of the data was performed. To generate a site wide estimate for gamma ray exposure, values were assembled for each of the 1787 grid blocks. Values for each grid block were presented as direct measurements taken at each grid point and as a range of exposures measured during the scan.

4.4.4 Estimated External Exposures for Y-12 Workers

The four aerial surveys discussed above present reasonable ranges of elevated external exposures. However, the purpose of these surveys was to identify specific sources of higher than background radiation levels. The focus of the latter aerial surveys was to isolate and identify sources such as waste pits and storage areas. The resulting isopleths from these surveys have relatively poor resolution and are not reliable for estimating a site wide average exposure rate. Some of the major sources identified by the aerial surveys were attributed to collimated sources that were not in constant operation. In addition, the isopleths generated by these surveys are dominated by the high radiation source areas and provide little or no definition for localized areas. Interpreting a site wide average was not possible from these aerial surveys.

Because of the limitations of the aerial surveys, it was decided to use the results of the 1987 outdoor scoping survey for estimating external exposures. The scoping survey is a comprehensive assessment of radiation exposures and encompasses all areas of the site. There are 1787 grids and the resolution of the grids (100 feet x100 feet to 200 feet x 200feet) ensures that all localized hot-spots are included. The purpose of the scoping survey was to locate and prioritize areas of concern

from both a worker health and safety and from an environmental assessment standpoint and is therefore most relevant to assessing worker exposure.

For this Technical Basis Document, the *highest* exposure reading from *either* the scan or the direct measurement presented in the scoping survey was used. This approach presented the most conservative method of estimating exposures and ensures that areas of high exposure levels within each grid were included in the site wide average. It was noted that numerous grid blocks exhibited high exposure readings, but these areas were not subjected to direct measurements. Higher readings were attributed to either shine from nearby buildings and storage areas or to localized hot-spots.

By utilizing the highest direct exposure value from either the scans or the direct readings, exposures attributable to shine or localized hot-spots were included in the assessment. Since the purpose of this assessment is to estimate doses received from ambient external radiation, neglecting these areas of high exposure would not encompass external exposures potentially received by people working in these areas.

Natural terrestrial background at Y-12 was inferred by the aerial survey conducted in 1973-1974 (EG&G 1976). The exposure rate (at 1 m above ground) ranged from 4 to 6 $\mu R\ h^{-1}$, excluding cosmic radiation. An exposure rate of 3.8 $\mu R\ h^{-1}$ was estimated as the exposure rate from cosmic radiation. The aerial estimates were made at one meter above ground and the results from the scoping survey were measured at ground surface. Thus, an estimated natural background rate (8 $\mu R\ h^{-1}$) was calculated by summing the lowest value of the background exposure rate range from the aerial survey and the cosmic radiation component.

The 1787 exposure measurements used for this analysis ranged from 4 to 1,500 $\mu R\ h^{-1}$. However 88% of the data was less than 100 $\mu R\ h^{-1}$ indicating a definitive skew to the data, and this was confirmed with plots of all data. Therefore, a lognormal distribution was used for the range of exposure rates presented in the scoping survey. The data are presented below.

	Measured exposure rate ($\mu R\ h^{-1}$)	**Measured exposure rate excluding background ($\mu R\ h^{-1}$)**
Minimum	4	0
Maximum	1500	1492
Geometric Mean (GM)	21	13
Geometric Standard Deviation (GSD)	3.0	
50^{th} Percentile	21	13
95^{th} Percentile	129	121

The highest exposure readings were generally attributed to the shine emanating from nearby buildings, storage areas or waste pits. Although these readings are not indicative of the level of radioactivity in soils and surfaces, contributions from shine are valid sources of exposure for workers.

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GLOSSARY

BEING PREPARED

ATTACHMENT D
OCCUPATIONAL ENVIRONMENTAL DOSE

LIST OF TABLES

D.1 Occupational Environmental Dose for Unmonitored Workers

The occupational environmental dose received by unmonitored workers is limited to exposures received while outside buildings and within the perimeter of the Y-12 Plant. Buildings and other operational units occupy the vast majority of the land area at Y-12. This assessment will quantify exposure for unmonitored workers who either work outdoors or otherwise spend time outside buildings. Based on the exposure assessment, the two exposure pathways are:

1. Inhalation of uranium in ambient air due to operational releases,

2. Direct external radiation exposure from radionuclides in soils and outdoor surfaces, as well as shine from buildings and operational units.

D.2 Intake of Radionuclides from On Site Releases of Radionuclides

Although other radionuclides have been present at Y-12, the primary source of airborne radioactive material is uranium from the various operations that have occurred over the years. Thus, intakes have been calculated only for $^{234/235}$U and ^{238}U. Only four monitoring stations are located on Y-12, so intakes have been calculated only for these locations (Tables D-1 to D-4). In addition, site-wide average concentrations based on the four stations have been calculated and are in Table D-5. The maximum intake is shown in Table D-6.

The on site concentrations of $^{234/235}$U and ^{238}U were estimated based on an empirical approach. The air concentrations and intakes were estimated using the 50th and 95th percentile values for the empirical dispersion coefficient (Chi/Q) for each station. Air concentrations (becquerel/cubic meter [Bq m^{-3}]) for all years from 1944 to 2002 were estimated based on the quantities of uranium released. Intakes (Bq y^{-1}) were estimated from the air concentrations based on an exposure assumption of 2000 h y^{-1} and an inhalation rate of 1.2 m^3 h^{-1}. Intakes were estimated for four locations within the

boundary of the facility. A site-wide average was also calculated from these four locations. In addition, maximum air concentrations and intakes are presented.

Table D-1. Calculated $^{234/235}U$ and ^{238}U air concentrations and intakes for Station 2.

	Station 2 Air Concentrations (Bq m^{-3})				Station 2 Intake (Bq y^{-1})			
	$^{234/235}U$		^{238}U		$^{234/235}U$		^{238}U	
YEAR	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
1944	4.41E-05	1.17E-04	2.02E-05	5.35E-05	0.1058	0.2800	0.0485	0.1283
1945	7.53E-05	1.99E-04	4.04E-05	1.07E-04	0.1807	0.4783	0.0969	0.2566
1946	5.69E-05	1.51E-04	2.39E-05	6.32E-05	0.1366	0.3616	0.0573	0.1516
1947	4.77E-05	1.26E-04	1.47E-05	3.89E-05	0.1146	0.3033	0.0353	0.0933
1948	3.12E-05	8.26E-05	4.04E-05	1.07E-04	0.0749	0.1983	0.0969	0.2566
1949	3.12E-05	8.26E-05	4.04E-05	1.07E-04	0.0749	0.1983	0.0969	0.2566
1950	3.12E-05	8.26E-05	4.04E-05	1.07E-04	0.0749	0.1983	0.0969	0.2566
1951	3.12E-05	8.26E-05	4.04E-05	1.07E-04	0.0749	0.1983	0.0969	0.2566
1952	3.12E-05	8.26E-05	4.04E-05	1.07E-04	0.0749	0.1983	0.0969	0.2566
1953	1.23E-04	3.26E-04	2.50E-04	6.61E-04	0.2952	0.7816	0.5993	1.5865
1954	1.06E-04	2.82E-04	2.35E-04	6.22E-04	0.2556	0.6766	0.5640	1.4932
1955	1.08E-04	2.87E-04	2.35E-04	6.22E-04	0.2600	0.6883	0.5640	1.4932
1956	5.88E-04	1.56E-03	1.84E-04	4.86E-04	1.4101	3.7329	0.4407	1.1665
1957	1.06E-03	2.82E-03	1.47E-04	3.89E-04	2.5558	6.7659	0.3525	0.9332
1958	3.19E-03	8.46E-03	3.30E-04	8.75E-04	7.6674	20.2976	0.7932	2.0998
1959	2.18E-03	5.78E-03	3.67E-04	9.72E-04	5.2438	13.8817	0.8813	2.3331
1960	4.46E-04	1.18E-03	5.69E-05	1.51E-04	1.0708	2.8347	0.1366	0.3616
1961	7.16E-04	1.90E-03	7.90E-05	2.09E-04	1.7186	4.5495	0.1895	0.5016
1962	7.73E-04	2.05E-03	8.45E-05	2.24E-04	1.8552	4.9111	0.2027	0.5366
1963	3.86E-04	1.02E-03	1.29E-04	3.40E-04	0.9254	2.4497	0.3085	0.8166
1964	1.25E-04	3.31E-04	1.67E-04	4.42E-04	0.2996	0.7932	0.4010	1.0615
1965	6.26E-04	1.66E-03	3.67E-05	9.72E-05	1.5026	3.9779	0.0881	0.2333
1966	2.00E-04	5.30E-04	5.69E-05	1.51E-04	0.4803	1.2715	0.1366	0.3616
1967	9.18E-05	2.43E-04	2.02E-05	5.35E-05	0.2203	0.5833	0.0485	0.1283
1968	4.04E-05	1.07E-04	2.75E-05	7.29E-05	0.0969	0.2566	0.0661	0.1750
1969	1.78E-04	4.71E-04	1.47E-05	3.89E-05	0.4274	1.1315	0.0353	0.0933
1970	2.92E-04	7.73E-04	1.65E-05	4.37E-05	0.7006	1.8548	0.0397	0.1050
1971	3.80E-04	1.01E-03	3.49E-05	9.24E-05	0.9122	2.4147	0.0837	0.2216
1972	6.72E-04	1.78E-03	5.14E-05	1.36E-04	1.6128	4.2695	0.1234	0.3266
1973	5.93E-04	1.57E-03	2.39E-05	6.32E-05	1.4233	3.7679	0.0573	0.1516
1974	5.14E-05	1.36E-04	1.29E-05	3.40E-05	0.1234	0.3266	0.0308	0.0817
1975	9.55E-05	2.53E-04	1.29E-05	3.40E-05	0.2291	0.6066	0.0308	0.0817
1976	6.06E-05	1.60E-04	1.29E-05	3.40E-05	0.1454	0.3850	0.0308	0.0817
1977	2.94E-05	7.78E-05	1.29E-05	3.40E-05	0.0705	0.1866	0.0308	0.0817
1978	3.12E-05	8.26E-05	1.29E-05	3.40E-05	0.0749	0.1983	0.0308	0.0817
1979	4.41E-05	1.17E-04	1.29E-05	3.40E-05	0.1058	0.2800	0.0308	0.0817
1980	8.63E-05	2.28E-04	1.29E-05	3.40E-05	0.2071	0.5483	0.0308	0.0817
1981	5.32E-05	1.41E-04	1.29E-05	3.40E-05	0.1278	0.3383	0.0308	0.0817
1982	8.81E-05	2.33E-04	1.29E-05	3.40E-05	0.2115	0.5599	0.0308	0.0817
1983	7.53E-05	1.99E-04	1.29E-05	3.40E-05	0.1807	0.4783	0.0308	0.0817
1984	6.43E-05	1.70E-04	2.02E-05	5.35E-05	0.1542	0.4083	0.0485	0.1283
1985	5.14E-05	1.36E-04	1.29E-05	3.40E-05	0.1234	0.3266	0.0308	0.0817
1986	6.43E-05	1.70E-04	1.29E-05	3.40E-05	0.1542	0.4083	0.0308	0.0817
1987	1.08E-04	2.87E-04	9.18E-06	2.43E-05	0.2600	0.6883	0.0220	0.0583
1988	5.51E-05	1.46E-04	9.18E-06	2.43E-05	0.1322	0.3500	0.0220	0.0583
1989	2.75E-05	7.29E-05	2.57E-06	6.80E-06	0.0661	0.1750	0.0062	0.0163
1990	1.47E-05	3.89E-05	1.29E-06	3.40E-06	0.0353	0.0933	0.0031	0.0082
1991	7.34E-06	1.94E-05	1.84E-06	4.86E-06	0.0176	0.0467	0.0044	0.0117
1992	7.34E-06	1.94E-05	1.10E-06	2.92E-06	0.0176	0.0467	0.0026	0.0070
1993	5.51E-06	1.46E-05	5.51E-07	1.46E-06	0.0132	0.0350	0.0013	0.0035
1994	5.51E-06	1.46E-05	3.67E-07	9.72E-07	0.0132	0.0350	0.0009	0.0023
1995	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024
1996	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024
1997	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024
1998	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024
1999	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024
2000	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024

2001	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024
2002	3.67E-06	9.72E-06	3.86E-07	1.02E-06	0.0088	0.0233	0.0009	0.0024

Table D-2. Calculated $^{234/235}U$ and ^{238}U air concentrations and intakes for Station 4.

	Station 4 Air Concentration (Bq m^{-3})				Station 4 Intake (Bq y^{-1})			
	$^{234/235}U$		^{238}U		$^{234/235}U$		^{238}U	
YEAR	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
1944	1.28E-04	7.75E-04	5.87E-05	3.55E-04	0.3072	1.8607	0.1408	0.8528
1945	2.19E-04	1.32E-03	1.17E-04	7.11E-04	0.5247	3.1788	0.2816	1.7057
1946	1.65E-04	1.00E-03	6.93E-05	4.20E-04	0.3967	2.4035	0.1664	1.0079
1947	1.39E-04	8.40E-04	4.27E-05	2.58E-04	0.3328	2.0158	0.1024	0.6202
1948	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1949	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1950	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1951	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1952	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1953	3.57E-04	2.16E-03	7.25E-04	4.39E-03	0.8575	5.1946	1.7406	10.5442
1954	3.09E-04	1.87E-03	6.83E-04	4.13E-03	0.7423	4.4968	1.6382	9.9239
1955	3.15E-04	1.91E-03	6.83E-04	4.13E-03	0.7551	4.5743	1.6382	9.9239
1956	1.71E-03	1.03E-02	5.33E-04	3.23E-03	4.0955	24.8098	1.2798	7.7531
1957	3.09E-03	1.87E-02	4.27E-04	2.58E-03	7.4230	44.9678	1.0239	6.2025
1958	9.28E-03	5.62E-02	9.60E-04	5.81E-03	22.2691	134.9034	2.3037	13.9555
1959	6.35E-03	3.84E-02	1.07E-03	6.46E-03	15.2300	92.2615	2.5597	15.5061
1960	1.30E-03	7.85E-03	1.65E-04	1.00E-03	3.1100	18.8400	0.3967	2.4035
1961	2.08E-03	1.26E-02	2.29E-04	1.39E-03	4.9914	30.2370	0.5503	3.3338
1962	2.25E-03	1.36E-02	2.45E-04	1.49E-03	5.3881	32.6404	0.5887	3.5664
1963	1.12E-03	6.78E-03	3.73E-04	2.26E-03	2.6877	16.2814	0.8959	5.4271
1964	3.63E-04	2.20E-03	4.85E-04	2.94E-03	0.8703	5.2721	1.1646	7.0553
1965	1.82E-03	1.10E-02	1.07E-04	6.46E-04	4.3642	26.4380	0.2560	1.5506
1966	5.81E-04	3.52E-03	1.65E-04	1.00E-03	1.3950	8.4508	0.3967	2.4035
1967	2.67E-04	1.62E-03	5.87E-05	3.55E-04	0.6399	3.8765	0.1408	0.8528
1968	1.17E-04	7.11E-04	8.00E-05	4.85E-04	0.2816	1.7057	0.1920	1.1630
1969	5.17E-04	3.13E-03	4.27E-05	2.58E-04	1.2414	7.5205	0.1024	0.6202
1970	8.48E-04	5.14E-03	4.80E-05	2.91E-04	2.0349	12.3274	0.1152	0.6978
1971	1.10E-03	6.69E-03	1.01E-04	6.14E-04	2.6493	16.0489	0.2432	1.4731
1972	1.95E-03	1.18E-02	1.49E-04	9.05E-04	4.6842	28.3762	0.3584	2.1709
1973	1.72E-03	1.04E-02	6.93E-05	4.20E-04	4.1339	25.0424	0.1664	1.0079
1974	1.49E-04	9.05E-04	3.73E-05	2.26E-04	0.3584	2.1709	0.0896	0.5427
1975	2.77E-04	1.68E-03	3.73E-05	2.26E-04	0.6655	4.0316	0.0896	0.5427
1976	1.76E-04	1.07E-03	3.73E-05	2.26E-04	0.4223	2.5585	0.0896	0.5427
1977	8.53E-05	5.17E-04	3.73E-05	2.26E-04	0.2048	1.2405	0.0896	0.5427
1978	9.07E-05	5.49E-04	3.73E-05	2.26E-04	0.2176	1.3180	0.0896	0.5427
1979	1.28E-04	7.75E-04	3.73E-05	2.26E-04	0.3072	1.8607	0.0896	0.5427
1980	2.51E-04	1.52E-03	3.73E-05	2.26E-04	0.6015	3.6439	0.0896	0.5427
1981	1.55E-04	9.37E-04	3.73E-05	2.26E-04	0.3712	2.2484	0.0896	0.5427
1982	2.56E-04	1.55E-03	3.73E-05	2.26E-04	0.6143	3.7215	0.0896	0.5427
1983	2.19E-04	1.32E-03	3.73E-05	2.26E-04	0.5247	3.1788	0.0896	0.5427
1984	1.87E-04	1.13E-03	5.87E-05	3.55E-04	0.4479	2.7136	0.1408	0.8528
1985	1.49E-04	9.05E-04	3.73E-05	2.26E-04	0.3584	2.1709	0.0896	0.5427
1986	1.87E-04	1.13E-03	3.73E-05	2.26E-04	0.4479	2.7136	0.0896	0.5427
1987	3.15E-04	1.91E-03	2.67E-05	1.62E-04	0.7551	4.5743	0.0640	0.3877
1988	1.60E-04	9.69E-04	2.67E-05	1.62E-04	0.3840	2.3259	0.0640	0.3877
1989	8.00E-05	4.85E-04	7.47E-06	4.52E-05	0.1920	1.1630	0.0179	0.1085
1990	4.27E-05	2.58E-04	3.73E-06	2.26E-05	0.1024	0.6202	0.0090	0.0543
1991	2.13E-05	1.29E-04	5.33E-06	3.23E-05	0.0512	0.3101	0.0128	0.0775
1992	2.13E-05	1.29E-04	3.20E-06	1.94E-05	0.0512	0.3101	0.0077	0.0465
1993	1.60E-05	9.69E-05	1.60E-06	9.69E-06	0.0384	0.2326	0.0038	0.0233
1994	1.60E-05	9.69E-05	1.07E-06	6.46E-06	0.0384	0.2326	0.0026	0.0155
1995	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1996	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1997	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1998	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1999	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
2000	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
2001	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
2002	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163

Table D-3. Calculated $^{234/235}U$ and ^{238}U air concentrations and intakes for Station 8.

	Station 8 Air Concentration (Bq m^{-3})				Station 8 Intake (Bq y^{-1})			
	$^{234/235}U$		^{238}U		$^{234/235}U$		^{238}U	
YEAR	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
1944	1.12E-04	6.69E-04	5.12E-05	3.06E-04	0.2680	1.6048	0.1228	0.7356
1945	1.91E-04	1.14E-03	1.02E-04	6.13E-04	0.4578	2.7416	0.2457	1.4711
1946	1.44E-04	8.64E-04	6.05E-05	3.62E-04	0.3462	2.0729	0.1452	0.8693
1947	1.21E-04	7.24E-04	3.72E-05	2.23E-04	0.2903	1.7386	0.0893	0.5349
1948	7.91E-05	4.74E-04	1.02E-04	6.13E-04	0.1898	1.1368	0.2457	1.4711
1949	7.91E-05	4.74E-04	1.02E-04	6.13E-04	0.1898	1.1368	0.2457	1.4711
1950	7.91E-05	4.74E-04	1.02E-04	6.13E-04	0.1898	1.1368	0.2457	1.4711
1951	7.91E-05	4.74E-04	1.02E-04	6.13E-04	0.1898	1.1368	0.2457	1.4711
1952	7.91E-05	4.74E-04	1.02E-04	6.13E-04	0.1898	1.1368	0.2457	1.4711
1953	3.12E-04	1.87E-03	6.33E-04	3.79E-03	0.7482	4.4802	1.5187	9.0941
1954	2.70E-04	1.62E-03	5.96E-04	3.57E-03	0.6477	3.8784	1.4293	8.5592
1955	2.75E-04	1.64E-03	5.96E-04	3.57E-03	0.6588	3.9452	1.4293	8.5592
1956	1.49E-03	8.92E-03	4.65E-04	2.79E-03	3.5733	21.3979	1.1167	6.6869
1957	2.70E-03	1.62E-02	3.72E-04	2.23E-03	6.4766	38.7837	0.8933	5.3495
1958	8.10E-03	4.85E-02	8.37E-04	5.02E-03	19.4298	116.3512	2.0100	12.0363
1959	5.54E-03	3.32E-02	9.31E-04	5.57E-03	13.2882	79.5735	2.2333	13.3737
1960	1.13E-03	6.77E-03	1.44E-04	8.64E-04	2.7135	16.2490	0.3462	2.0729
1961	1.81E-03	1.09E-02	2.00E-04	1.20E-03	4.3550	26.0787	0.4802	2.8753
1962	1.96E-03	1.17E-02	2.14E-04	1.28E-03	4.7011	28.1516	0.5137	3.0760
1963	9.77E-04	5.85E-03	3.26E-04	1.95E-03	2.3450	14.0424	0.7817	4.6808
1964	3.16E-04	1.89E-03	4.23E-04	2.54E-03	0.7593	4.5471	1.0162	6.0850
1965	1.59E-03	9.50E-03	9.31E-05	5.57E-04	3.8078	22.8022	0.2233	1.3374
1966	5.07E-04	3.04E-03	1.44E-04	8.64E-04	1.2172	7.2887	0.3462	2.0729
1967	2.33E-04	1.39E-03	5.12E-05	3.06E-04	0.5583	3.3434	0.1228	0.7356
1968	1.02E-04	6.13E-04	6.98E-05	4.18E-04	0.2457	1.4711	0.1675	1.0030
1969	4.51E-04	2.70E-03	3.72E-05	2.23E-04	1.0832	6.4862	0.0893	0.5349
1970	7.40E-04	4.43E-03	4.19E-05	2.51E-04	1.7755	10.6321	0.1005	0.6018
1971	9.63E-04	5.77E-03	8.84E-05	5.29E-04	2.3115	13.8418	0.2122	1.2705
1972	1.70E-03	1.02E-02	1.30E-04	7.80E-04	4.0870	24.4739	0.3127	1.8723
1973	1.50E-03	9.00E-03	6.05E-05	3.62E-04	3.6068	21.5985	0.1452	0.8693
1974	1.30E-04	7.80E-04	3.26E-05	1.95E-04	0.3127	1.8723	0.0782	0.4681
1975	2.42E-04	1.45E-03	3.26E-05	1.95E-04	0.5807	3.4772	0.0782	0.4681
1976	1.54E-04	9.19E-04	3.26E-05	1.95E-04	0.3685	2.2067	0.0782	0.4681
1977	7.44E-05	4.46E-04	3.26E-05	1.95E-04	0.1787	1.0699	0.0782	0.4681
1978	7.91E-05	4.74E-04	3.26E-05	1.95E-04	0.1898	1.1368	0.0782	0.4681
1979	1.12E-04	6.69E-04	3.26E-05	1.95E-04	0.2680	1.6048	0.0782	0.4681
1980	2.19E-04	1.31E-03	3.26E-05	1.95E-04	0.5248	3.1428	0.0782	0.4681
1981	1.35E-04	8.08E-04	3.26E-05	1.95E-04	0.3238	1.9392	0.0782	0.4681
1982	2.23E-04	1.34E-03	3.26E-05	1.95E-04	0.5360	3.2097	0.0782	0.4681
1983	1.91E-04	1.14E-03	3.26E-05	1.95E-04	0.4578	2.7416	0.0782	0.4681
1984	1.63E-04	9.75E-04	5.12E-05	3.06E-04	0.3908	2.3404	0.1228	0.7356
1985	1.30E-04	7.80E-04	3.26E-05	1.95E-04	0.3127	1.8723	0.0782	0.4681
1986	1.63E-04	9.75E-04	3.26E-05	1.95E-04	0.3908	2.3404	0.0782	0.4681
1987	2.75E-04	1.64E-03	2.33E-05	1.39E-04	0.6588	3.9452	0.0558	0.3343
1988	1.40E-04	8.36E-04	2.33E-05	1.39E-04	0.3350	2.0061	0.0558	0.3343
1989	6.98E-05	4.18E-04	6.51E-06	3.90E-05	0.1675	1.0030	0.0156	0.0936
1990	3.72E-05	2.23E-04	3.26E-06	1.95E-05	0.0893	0.5349	0.0078	0.0468
1991	1.86E-05	1.11E-04	4.65E-06	2.79E-05	0.0447	0.2675	0.0112	0.0669
1992	1.86E-05	1.11E-04	2.79E-06	1.67E-05	0.0447	0.2675	0.0067	0.0401
1993	1.40E-05	8.36E-05	1.40E-06	8.36E-06	0.0335	0.2006	0.0033	0.0201
1994	1.40E-05	8.36E-05	9.31E-07	5.57E-06	0.0335	0.2006	0.0022	0.0134
1995	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
1996	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
1997	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
1998	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
1999	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
2000	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
2001	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140
2002	9.31E-06	5.57E-05	9.77E-07	5.85E-06	0.0223	0.1337	0.0023	0.0140

Table D-4. Calculated $^{234/235}U$ and ^{238}U air concentrations and intakes for Station 12.

	Station 12 Air Concentration (Bq m^{-3})				Station 12 Intake (Bq y^{-1})			
	$^{234/235}U$		^{238}U		$^{234/235}U$		^{238}U	
YEAR	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
1944	4.03E-05	1.70E-04	1.85E-05	7.81E-05	0.0967	0.4089	0.0443	0.1874
1945	6.88E-05	2.91E-04	3.69E-05	1.56E-04	0.1652	0.6986	0.0886	0.3748
1946	5.20E-05	2.20E-04	2.18E-05	9.23E-05	0.1249	0.5282	0.0524	0.2215
1947	4.36E-05	1.85E-04	1.34E-05	5.68E-05	0.1048	0.4430	0.0322	0.1363
1948	2.85E-05	1.21E-04	3.69E-05	1.56E-04	0.0685	0.2897	0.0886	0.3748
1949	2.85E-05	1.21E-04	3.69E-05	1.56E-04	0.0685	0.2897	0.0886	0.3748
1950	2.85E-05	1.21E-04	3.69E-05	1.56E-04	0.0685	0.2897	0.0886	0.3748
1951	2.85E-05	1.21E-04	3.69E-05	1.56E-04	0.0685	0.2897	0.0886	0.3748
1952	2.85E-05	1.21E-04	3.69E-05	1.56E-04	0.0685	0.2897	0.0886	0.3748
1953	1.12E-04	4.76E-04	2.28E-04	9.66E-04	0.2700	1.1416	0.5480	2.3172
1954	9.74E-05	4.12E-04	2.15E-04	9.09E-04	0.2337	0.9882	0.5157	2.1809
1955	9.90E-05	4.19E-04	2.15E-04	9.09E-04	0.2377	1.0053	0.5157	2.1809
1956	5.37E-04	2.27E-03	1.68E-04	7.10E-04	1.2893	5.4523	0.4029	1.7039
1957	9.74E-04	4.12E-03	1.34E-04	5.68E-04	2.3369	9.8824	0.3223	1.3631
1958	2.92E-03	1.24E-02	3.02E-04	1.28E-03	7.0107	29.6471	0.7252	3.0669
1959	2.00E-03	8.45E-03	3.36E-04	1.42E-03	4.7947	20.2759	0.8058	3.4077
1960	4.08E-04	1.73E-03	5.20E-05	2.20E-04	0.9791	4.1404	0.1249	0.5282
1961	6.55E-04	2.77E-03	7.22E-05	3.05E-04	1.5714	6.6450	0.1733	0.7327
1962	7.07E-04	2.99E-03	7.72E-05	3.27E-04	1.6963	7.1732	0.1853	0.7838
1963	3.53E-04	1.49E-03	1.18E-04	4.97E-04	0.8461	3.5781	0.2820	1.1927
1964	1.14E-04	4.83E-04	1.53E-04	6.46E-04	0.2740	1.1586	0.3667	1.5505
1965	5.72E-04	2.42E-03	3.36E-05	1.42E-04	1.3739	5.8102	0.0806	0.3408
1966	1.83E-04	7.74E-04	5.20E-05	2.20E-04	0.4392	1.8572	0.1249	0.5282
1967	8.39E-05	3.55E-04	1.85E-05	7.81E-05	0.2015	0.8519	0.0443	0.1874
1968	3.69E-05	1.56E-04	2.52E-05	1.06E-04	0.0886	0.3748	0.0604	0.2556
1969	1.63E-04	6.89E-04	1.34E-05	5.68E-05	0.3908	1.6527	0.0322	0.1363
1970	2.67E-04	1.13E-03	1.51E-05	6.39E-05	0.6406	2.7091	0.0363	0.1533
1971	3.48E-04	1.47E-03	3.19E-05	1.35E-04	0.8340	3.5270	0.0766	0.3237
1972	6.14E-04	2.60E-03	4.70E-05	1.99E-04	1.4747	6.2361	0.1128	0.4771
1973	5.42E-04	2.29E-03	2.18E-05	9.23E-05	1.3014	5.5035	0.0524	0.2215
1974	4.70E-05	1.99E-04	1.18E-05	4.97E-05	0.1128	0.4771	0.0282	0.1193
1975	8.73E-05	3.69E-04	1.18E-05	4.97E-05	0.2095	0.8860	0.0282	0.1193
1976	5.54E-05	2.34E-04	1.18E-05	4.97E-05	0.1330	0.5623	0.0282	0.1193
1977	2.69E-05	1.14E-04	1.18E-05	4.97E-05	0.0645	0.2726	0.0282	0.1193
1978	2.85E-05	1.21E-04	1.18E-05	4.97E-05	0.0685	0.2897	0.0282	0.1193
1979	4.03E-05	1.70E-04	1.18E-05	4.97E-05	0.0967	0.4089	0.0282	0.1193
1980	7.89E-05	3.34E-04	1.18E-05	4.97E-05	0.1894	0.8008	0.0282	0.1193
1981	4.87E-05	2.06E-04	1.18E-05	4.97E-05	0.1168	0.4941	0.0282	0.1193
1982	8.06E-05	3.41E-04	1.18E-05	4.97E-05	0.1934	0.8179	0.0282	0.1193
1983	6.88E-05	2.91E-04	1.18E-05	4.97E-05	0.1652	0.6986	0.0282	0.1193
1984	5.88E-05	2.48E-04	1.85E-05	7.81E-05	0.1410	0.5964	0.0443	0.1874
1985	4.70E-05	1.99E-04	1.18E-05	4.97E-05	0.1128	0.4771	0.0282	0.1193
1986	5.88E-05	2.48E-04	1.18E-05	4.97E-05	0.1410	0.5964	0.0282	0.1193
1987	9.90E-05	4.19E-04	8.39E-06	3.55E-05	0.2377	1.0053	0.0201	0.0852
1988	5.04E-05	2.13E-04	8.39E-06	3.55E-05	0.1209	0.5112	0.0201	0.0852
1989	2.52E-05	1.06E-04	2.35E-06	9.94E-06	0.0604	0.2556	0.0056	0.0239
1990	1.34E-05	5.68E-05	1.18E-06	4.97E-06	0.0322	0.1363	0.0028	0.0119
1991	6.72E-06	2.84E-05	1.68E-06	7.10E-06	0.0161	0.0682	0.0040	0.0170
1992	6.72E-06	2.84E-05	1.01E-06	4.26E-06	0.0161	0.0682	0.0024	0.0102
1993	5.04E-06	2.13E-05	5.04E-07	2.13E-06	0.0121	0.0511	0.0012	0.0051
1994	5.04E-06	2.13E-05	3.36E-07	1.42E-06	0.0121	0.0511	0.0008	0.0034
1995	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
1996	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
1997	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
1998	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
1999	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
2000	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
2001	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036
2002	3.36E-06	1.42E-05	3.53E-07	1.49E-06	0.0081	0.0341	0.0008	0.0036

Table D-5. Site wide $^{234/235}U$ and ^{238}U air concentrations and intakes based on average air concentrations for Stations 2, 4, 8 and 12.

	Site Wide Average Air Concentration (Bq m^{-3})				Site Wide Average Intake (Bq y^{-1})			
	$^{234/235}U$		^{238}U		$^{234/235}U$		^{238}U	
YEAR	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
1944	8.10E-05	4.33E-04	3.71E-05	1.98E-04	0.1944	1.0386	0.0891	0.4760
1945	1.38E-04	7.39E-04	7.43E-05	3.97E-04	0.3321	1.7743	0.1782	0.9521
1946	1.05E-04	5.59E-04	4.39E-05	2.34E-04	0.2511	1.3415	0.1053	0.5626
1947	8.78E-05	4.69E-04	2.70E-05	1.44E-04	0.2106	1.1252	0.0648	0.3462
1948	5.74E-05	3.07E-04	7.43E-05	3.97E-04	0.1377	0.7357	0.1782	0.9521
1949	5.74E-05	3.07E-04	7.43E-05	3.97E-04	0.1377	0.7357	0.1782	0.9521
1950	5.74E-05	3.07E-04	7.43E-05	3.97E-04	0.1377	0.7357	0.1782	0.9521
1951	5.74E-05	3.07E-04	7.43E-05	3.97E-04	0.1377	0.7357	0.1782	0.9521
1952	5.74E-05	3.07E-04	7.43E-05	3.97E-04	0.1377	0.7357	0.1782	0.9521
1953	2.26E-04	1.21E-03	4.59E-04	2.45E-03	0.5427	2.8995	1.1016	5.8855
1954	1.96E-04	1.05E-03	4.32E-04	2.31E-03	0.4698	2.5100	1.0368	5.5393
1955	1.99E-04	1.06E-03	4.32E-04	2.31E-03	0.4779	2.5533	1.0368	5.5393
1956	1.08E-03	5.77E-03	3.38E-04	1.80E-03	2.5920	13.8482	0.8100	4.3276
1957	1.96E-03	1.05E-02	2.70E-04	1.44E-03	4.6981	25.0999	0.6480	3.4621
1958	5.87E-03	3.14E-02	6.08E-04	3.25E-03	14.0943	75.2998	1.4580	7.7896
1959	4.02E-03	2.15E-02	6.75E-04	3.61E-03	9.6392	51.4982	1.6200	8.6552
1960	8.20E-04	4.38E-03	1.05E-04	5.59E-04	1.9683	10.5160	0.2511	1.3415
1961	1.32E-03	7.03E-03	1.45E-04	7.75E-04	3.1591	16.8775	0.3483	1.8609
1962	1.42E-03	7.59E-03	1.55E-04	8.29E-04	3.4102	18.2191	0.3726	1.9907
1963	7.09E-04	3.79E-03	2.36E-04	1.26E-03	1.7010	9.0879	0.5670	3.0293
1964	2.30E-04	1.23E-03	3.07E-04	1.64E-03	0.5508	2.9428	0.7371	3.9381
1965	1.15E-03	6.15E-03	6.75E-05	3.61E-04	2.7621	14.7570	0.1620	0.8655
1966	3.68E-04	1.97E-03	1.05E-04	5.59E-04	0.8829	4.7171	0.2511	1.3415
1967	1.69E-04	9.02E-04	3.71E-05	1.98E-04	0.4050	2.1638	0.0891	0.4760
1968	7.43E-05	3.97E-04	5.06E-05	2.70E-04	0.1782	0.9521	0.1215	0.6491
1969	3.27E-04	1.75E-03	2.70E-05	1.44E-04	0.7857	4.1977	0.0648	0.3462
1970	5.37E-04	2.87E-03	3.04E-05	1.62E-04	1.2879	6.8808	0.0729	0.3895
1971	6.99E-04	3.73E-03	6.41E-05	3.43E-04	1.6767	8.9581	0.1539	0.8222
1972	1.24E-03	6.60E-03	9.45E-05	5.05E-04	2.9647	15.8389	0.2268	1.2117
1973	1.09E-03	5.82E-03	4.39E-05	2.34E-04	2.6163	13.9781	0.1053	0.5626
1974	9.45E-05	5.05E-04	2.36E-05	1.26E-04	0.2268	1.2117	0.0567	0.3029
1975	1.76E-04	9.38E-04	2.36E-05	1.26E-04	0.4212	2.2503	0.0567	0.3029
1976	1.11E-04	5.95E-04	2.36E-05	1.26E-04	0.2673	1.4281	0.0567	0.3029
1977	5.40E-05	2.89E-04	2.36E-05	1.26E-04	0.1296	0.6924	0.0567	0.3029
1978	5.74E-05	3.07E-04	2.36E-05	1.26E-04	0.1377	0.7357	0.0567	0.3029
1979	8.10E-05	4.33E-04	2.36E-05	1.26E-04	0.1944	1.0386	0.0567	0.3029
1980	1.59E-04	8.47E-04	2.36E-05	1.26E-04	0.3807	2.0340	0.0567	0.3029
1981	9.79E-05	5.23E-04	2.36E-05	1.26E-04	0.2349	1.2550	0.0567	0.3029
1982	1.62E-04	8.66E-04	2.36E-05	1.26E-04	0.3888	2.0772	0.0567	0.3029
1983	1.38E-04	7.39E-04	2.36E-05	1.26E-04	0.3321	1.7743	0.0567	0.3029
1984	1.18E-04	6.31E-04	3.71E-05	1.98E-04	0.2835	1.5147	0.0891	0.4760
1985	9.45E-05	5.05E-04	2.36E-05	1.26E-04	0.2268	1.2117	0.0567	0.3029
1986	1.18E-04	6.31E-04	2.36E-05	1.26E-04	0.2835	1.5147	0.0567	0.3029
1987	1.99E-04	1.06E-03	1.69E-05	9.02E-05	0.4779	2.5533	0.0405	0.2164
1988	1.01E-04	5.41E-04	1.69E-05	9.02E-05	0.2430	1.2983	0.0405	0.2164
1989	5.06E-05	2.70E-04	4.73E-06	2.52E-05	0.1215	0.6491	0.0113	0.0606
1990	2.70E-05	1.44E-04	2.36E-06	1.26E-05	0.0648	0.3462	0.0057	0.0303
1991	1.35E-05	7.21E-05	3.38E-06	1.80E-05	0.0324	0.1731	0.0081	0.0433
1992	1.35E-05	7.21E-05	2.03E-06	1.08E-05	0.0324	0.1731	0.0049	0.0260
1993	1.01E-05	5.41E-05	1.01E-06	5.41E-06	0.0243	0.1298	0.0024	0.0130
1994	1.01E-05	5.41E-05	6.75E-07	3.61E-06	0.0243	0.1298	0.0016	0.0087
1995	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
1996	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
1997	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
1998	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
1999	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
2000	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
2001	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091
2002	6.75E-06	3.61E-05	7.09E-07	3.79E-06	0.0162	0.0866	0.0017	0.0091

Table D-6. Maximum $^{234/235}U$ and ^{238}U air concentrations and intakes.

	Station 4 Air Concentration (Bq m^{-3})				Station 4 Intake (Bq y^{-1})			
	$^{234/235}U$		^{238}U		$^{234/235}U$		^{238}U	
YEAR	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
1944	1.28E-04	7.75E-04	5.87E-05	3.55E-04	0.3072	1.8607	0.1408	0.8528
1945	2.19E-04	1.32E-03	1.17E-04	7.11E-04	0.5247	3.1788	0.2816	1.7057
1946	1.65E-04	1.00E-03	6.93E-05	4.20E-04	0.3967	2.4035	0.1664	1.0079
1947	1.39E-04	8.40E-04	4.27E-05	2.58E-04	0.3328	2.0158	0.1024	0.6202
1948	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1949	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1950	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1951	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1952	9.07E-05	5.49E-04	1.17E-04	7.11E-04	0.2176	1.3180	0.2816	1.7057
1953	3.57E-04	2.16E-03	7.25E-04	4.39E-03	0.8575	5.1946	1.7406	10.5442
1954	3.09E-04	1.87E-03	6.83E-04	4.13E-03	0.7423	4.4968	1.6382	9.9239
1955	3.15E-04	1.91E-03	6.83E-04	4.13E-03	0.7551	4.5743	1.6382	9.9239
1956	1.71E-03	1.03E-02	5.33E-04	3.23E-03	4.0955	24.8098	1.2798	7.7531
1957	3.09E-03	1.87E-02	4.27E-04	2.58E-03	7.4230	44.9678	1.0239	6.2025
1958	9.28E-03	5.62E-02	9.60E-04	5.81E-03	22.2691	134.9034	2.3037	13.9555
1959	6.35E-03	3.84E-02	1.07E-03	6.46E-03	15.2300	92.2615	2.5597	15.5061
1960	1.30E-03	7.85E-03	1.65E-04	1.00E-03	3.1100	18.8400	0.3967	2.4035
1961	2.08E-03	1.26E-02	2.29E-04	1.39E-03	4.9914	30.2370	0.5503	3.3338
1962	2.25E-03	1.36E-02	2.45E-04	1.49E-03	5.3881	32.6404	0.5887	3.5664
1963	1.12E-03	6.78E-03	3.73E-04	2.26E-03	2.6877	16.2814	0.8959	5.4271
1964	3.63E-04	2.20E-03	4.85E-04	2.94E-03	0.8703	5.2721	1.1646	7.0553
1965	1.82E-03	1.10E-02	1.07E-04	6.46E-04	4.3642	26.4380	0.2560	1.5506
1966	5.81E-04	3.52E-03	1.65E-04	1.00E-03	1.3950	8.4508	0.3967	2.4035
1967	2.67E-04	1.62E-03	5.87E-05	3.55E-04	0.6399	3.8765	0.1408	0.8528
1968	1.17E-04	7.11E-04	8.00E-05	4.85E-04	0.2816	1.7057	0.1920	1.1630
1969	5.17E-04	3.13E-03	4.27E-05	2.58E-04	1.2414	7.5205	0.1024	0.6202
1970	8.48E-04	5.14E-03	4.80E-05	2.91E-04	2.0349	12.3274	0.1152	0.6978
1971	1.10E-03	6.69E-03	1.01E-04	6.14E-04	2.6493	16.0489	0.2432	1.4731
1972	1.95E-03	1.18E-02	1.49E-04	9.05E-04	4.6842	28.3762	0.3584	2.1709
1973	1.72E-03	1.04E-02	6.93E-05	4.20E-04	4.1339	25.0424	0.1664	1.0079
1974	1.49E-04	9.05E-04	3.73E-05	2.26E-04	0.3584	2.1709	0.0896	0.5427
1975	2.77E-04	1.68E-03	3.73E-05	2.26E-04	0.6655	4.0316	0.0896	0.5427
1976	1.76E-04	1.07E-03	3.73E-05	2.26E-04	0.4223	2.5585	0.0896	0.5427
1977	8.53E-05	5.17E-04	3.73E-05	2.26E-04	0.2048	1.2405	0.0896	0.5427
1978	9.07E-05	5.49E-04	3.73E-05	2.26E-04	0.2176	1.3180	0.0896	0.5427
1979	1.28E-04	7.75E-04	3.73E-05	2.26E-04	0.3072	1.8607	0.0896	0.5427
1980	2.51E-04	1.52E-03	3.73E-05	2.26E-04	0.6015	3.6439	0.0896	0.5427
1981	1.55E-04	9.37E-04	3.73E-05	2.26E-04	0.3712	2.2484	0.0896	0.5427
1982	2.56E-04	1.55E-03	3.73E-05	2.26E-04	0.6143	3.7215	0.0896	0.5427
1983	2.19E-04	1.32E-03	3.73E-05	2.26E-04	0.5247	3.1788	0.0896	0.5427
1984	1.87E-04	1.13E-03	5.87E-05	3.55E-04	0.4479	2.7136	0.1408	0.8528
1985	1.49E-04	9.05E-04	3.73E-05	2.26E-04	0.3584	2.1709	0.0896	0.5427
1986	1.87E-04	1.13E-03	3.73E-05	2.26E-04	0.4479	2.7136	0.0896	0.5427
1987	3.15E-04	1.91E-03	2.67E-05	1.62E-04	0.7551	4.5743	0.0640	0.3877
1988	1.60E-04	9.69E-04	2.67E-05	1.62E-04	0.3840	2.3259	0.0640	0.3877
1989	8.00E-05	4.85E-04	7.47E-06	4.52E-05	0.1920	1.1630	0.0179	0.1085
1990	4.27E-05	2.58E-04	3.73E-06	2.26E-05	0.1024	0.6202	0.0090	0.0543
1991	2.13E-05	1.29E-04	5.33E-06	3.23E-05	0.0512	0.3101	0.0128	0.0775
1992	2.13E-05	1.29E-04	3.20E-06	1.94E-05	0.0512	0.3101	0.0077	0.0465
1993	1.60E-05	9.69E-05	1.60E-06	9.69E-06	0.0384	0.2326	0.0038	0.0233
1994	1.60E-05	9.69E-05	1.07E-06	6.46E-06	0.0384	0.2326	0.0026	0.0155
1995	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1996	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1997	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1998	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
1999	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
2000	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
2001	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163
2002	1.07E-05	6.46E-05	1.12E-06	6.78E-06	0.0256	0.1551	0.0027	0.0163

D.3 Ambient External Dose

Ambient radiation levels will be typically measured by the monitored worker's personal dosimeters. However, for the unmonitored worker, external radiation exposures were estimated from prior characterization efforts at Y-12.

There are two potential sources of external exposures received by workers at the Y-12 facility:

1. Exposures from the deposition of radionuclides released as a consequence of facility operations,

2. Exposures received from radiation levels emanating from buildings and storage areas.

The data from the scoping survey should be used to calculate an external dose for unmonitored workers (Foley and Carrier 1990). The dose rates shown in Table D-7 represent the external exposure rates measured site wide. The exposure rates were converted to dose equivalent rates assuming a quality factor of one (1).

Table D-7. External dose rates outside buildings on Y-12 site.

	Measured exposure rate ($\mu R\ h^{-1}$)	**Dose rate excluding background ($\mu rem\ h^{-1}$)**
Minimum	4	0
Maximum	1500	1492
Geometric Mean (GM)	21	13
Geometric Standard Deviation (GSD)	3.0	
50^{th} Percentile	21	13
95^{th} Percentile	129	121