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Radiation Monitoring at Pantex: A Review of the Bureau of Radiation Control Environmental Data 1993-2003

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A black and white photograph of two wheat stalks against a cloudy sky. The stalks are in the foreground, with their heads pointing upwards and slightly to the right. The sky is filled with soft, white clouds, and the overall tone is serene and natural.

Radiation Monitoring at Pantex

A Review of
the Bureau of Radiation Control
Environmental Data
1993 – 2003

the Peace Farm

August 2005

the Peace Farm was established in 1986
as an information source about the Pantex Plant
and to stand as a visible witness
against the weapons of mass destruction being assembled there.

Supported by a grant from the Citizens' Monitoring and Technical Assessment Fund.

Radiation Monitoring at Pantex

A Review of the Bureau of Radiation Control Environmental Data 1993 – 2003

by Pam Allison

*for
the Peace Farm*

August 2005

Table of Contents

KEY FINDINGS	1
1.0 Introduction	2
2.0 Purpose of this Project	2
3.0 Radionuclides and Radiation Types Monitored	3
3.1 Alpha and Beta Radiation	4
3.2 Tritium	5
3.3 Plutonium-239	7
3.4 Radium-226	7
3.5 Uranium-234, 235, and 238	7
4.0 Air	7
4.1 Special Issues of Concern	8
4.2 Alpha and Beta Radiation and Tritium	9
4.3 Radium-226	9
4.4 Uranium-234, 235, and 238	9
4.5 Resulting Questions or Concerns – Air Monitoring	10
5.0 Crops	10
5.1 Alpha and Beta Radiation	11
5.2 Tritium	11
5.3 Radium-226 and Uranium-234, 235, and 238	11
5.4 Resulting Questions or Concerns – Crop Monitoring	11
6.0 Milk	11
6.1 Alpha and Beta Radiation and Tritium	12
6.2 Radium-226	12
6.3 Uranium-234, 235, and 238	13
6.4 Resulting Questions or Concerns – Milk Monitoring	13
7.0 Vegetation	13
7.1 Alpha and Beta Radiation	14
7.2 Tritium, Radium-226, and Uranium-234, 235, and 238	14
7.3 Resulting Questions or Concerns – Vegetation Monitoring	14
8.0 Sediment	15
8.1 Alpha and Beta Radiation	15
8.2 Tritium	15
8.3 Radium-226, and Uranium-234, 235, and 238	16
8.4 Resulting Questions or Concerns – Sediments Monitoring	16
9.0 Soils	16
9.1 Alpha and Beta Radiation	17
9.2 Tritium	17
9.3 Radium-226 and Uranium-234, 235, and 238	17
9.4 Resulting Questions or Concerns – Soils Monitoring	17
10.0 Water – Surface, Ground, and Drinking	17
10.1 Alpha and Beta Radiation	18
10.2 Tritium	18
10.3 Radium-226 and Uranium-234, 235, and 238	18
10.4 Resulting Questions or Concerns – Water Monitoring	19
11.0 Conclusions	20
12.0 References Cited	20

List of Tables

Table 1. Years radionuclides or radiation were monitored by the BRC for each environmental media around the Pantex Site for the years 1993 through 2003.

Table 2. Alpha radiation – Numbers of locations and samples, dates, and summary of results for environmental media monitored for Alpha Radiation. Results for water samples are in uCi/mL; all other media results are reported in uCi/g.

Table 3. Beta Radiation – Numbers of locations and samples, dates, and summary of results for environmental media monitored for Beta Radiation. Results for water samples are in uCi/mL; all other samples are reported in uCi/g.

Table 4. Maximum concentrations and annual averages of Tritium in air for sampling location PA-AR-06, as reported in Annual Site Environmental reports by the Pantex Plant.

Table 5. Time periods in which air sampling stations were used and total number of samples per year.

Table 6. Radium-226 in air by location, showing ranges and average values for measurements reported to have exceeded detection limits.

Table 7. Summary data for Uranium-234 and Uranium-238 in air.

Table 8. Number of crop samples collected and analyzed per year.

Table 9. Other values reported to be above detection-levels reported from crop samples.

Table 10. Number of Milk Samples by location and year for Uranium-234 and Uranium-238.

Table 11. Analyses of Radium-226 in Milk (in uCi/mL).

Table 12. Numbers of Vegetation samples by location and year.

Table 13. Summary of Results for Radium-226 and Uranium in Vegetation.

Table 14. Distribution of numbers of samples in Sediments by location and year.

Table 15. Summary of Results for Radium-226 and Uranium in Sediments.

Table 16. Distribution of numbers of soils samples by location and year.

Table 17. Summary of Results for Radium-226 and Uranium in Soils (in uCi/g).

Table 18. Assignments of water samples to Drinking (D), Ground (G), or Surface Water (S) according to location and year.

Table 19. Uranium-234 and -238 and Radium-226 in Water Samples

Table 20. Comparison of values reported for Radium-226 in water samples to the primary Drinking Water Standard.

KEY FINDINGS

- Radium-226 values in surface water and groundwater exceed the Primary Drinking Water Standard.
- The detection limits for Radium-226 in many instances exceed the Primary Drinking Water Standard by a factor of 10 or more.
- Samples were not analyzed for Radium-228, even though results for Radium-226 exceed or approach the Primary Drinking Water Standard and the few analyses conducted by Pantex on both isotopes indicate that Radium-228 at Pantex is more abundant than Radium-226.
- Tritium – a major concern as a contaminant at Pantex following the tritium release event and subsequent venting for years following the Cell One Incident at Pantex in 1989– was not monitored in air or milk.
- Alpha and Beta Radiation was monitored only briefly (1993 – 1995).
- Radium-226 was monitored in milk at three locations in the vicinity of Pantex from 1993-2001; however, the analyses were discontinued, even though the 2001 data suggested an uptrend.
- Between 1993 and 2003 (inclusive), 2588 samples were collected and analyzed for Plutonium with all but one result reported below detection.
- Air monitoring occurred every 6th day between 1993 and October 1997, rather than a more random, less predictable method for collecting air samples.
- The laboratory detection limits for Radium-226 in air samples seem to have changed on or about June 1, 1998. Although there may have been good reason to do so, the rationale for the change was not found in the 1998 report.

1.0 Introduction

The U.S. Department of Energy/National Nuclear Security Administration Pantex Plant (hereinafter, Pantex) is located 17 miles northeast of Amarillo, in Carson County, Texas (Figure 1). Its primary mission is to assemble, evaluate, repair, retrofit, and disassemble nuclear weapons; provide interim storage for plutonium pits; and develop, fabricate, and test chemical explosives and explosive components for nuclear weapons (BWXT-Pantex L.L.C. [hereinafter BWXT], 2004).

The Texas Department of Health Bureau of Radiation Control (BRC) conducted radiation and radionuclide monitoring in a variety of environmental media around the Pantex Plant from 1993 to the present. At the time of this review, results for the years 1993-2003 were provided in multi-year or annual summaries, listed in the References Cited section of this evaluation.

The laboratory analyses were performed by the Texas Department of Health, Bureau of Laboratories. Each year's summary disclosed the Quality Assurance and Quality Control evaluations for the laboratory in its appendices.

The rationale for the BRC's selection of sampling locations, duration of monitoring for specific radionuclides or types of radiation, and discussions about the reported analytical results were not included in the reports. The BRC stated that "analysis of samples is concentrated on determining presence of any special nuclear material" (BRC 2004, p. 61), and provided the following conclusions:

For years 1993-1997:

"All data was reviewed and the determination made that no regulatory limits were exceeded by any of the licensees nor were there any sample results which indicated a release of radioactive material to the environment that exceeded the regulatory or license limits of any other agency such as the U.S. Nuclear Regulatory Commission or the U.S. Department of Energy." (BRC, April 1999, p. 3).

For year 1998:

"All data were reviewed and the determination made that no regulatory limits were exceeded at any of the monitored facilities nor were there any sample results which indicated a release of radioactive material to the environment that exceeded the regulatory or license limits of The Texas Department of Health or any other agency such as the U.S. Nuclear Regulatory Commission or the U.S. Department of Energy." (BRC, September 1999, p. 3).

For years 2001, 2002, and 2003:

"Analysis of sample data from the monitored facilities indicated no release of radioactive material to the environment that exceeded the regulatory or license limits of the Texas Department of Health or any other agency such as the U.S. Nuclear Regulatory Commission or the U.S. Department of Energy." (BRC, 2002, p. 3; BRC, 2003, p. 3; BRC, 2004, p. 3)

Conclusions were not found in the 1999 and 2000 summary reports.

2.0 Purpose of this Project

This review was undertaken to (1) identify and understand what media, constituents, and locations have been monitored; (2) review and compare the reported analytical results between and among media and locations; (3) identify data gaps; (4) identify any data trends to the extent possible; (5) compare results to available health standards; and (6) identify any questions about the radiation monitoring by the BRC that resulted from this review.

Also, it was hoped to determine whether the gathering of data was done in a comprehensive manner to enable the BRC to confidently determine the extent of any exposures and address any expected health concerns.

Data from the BRC was acquired as bound reports for each year of record. The data were manually transferred into a spreadsheet for analyses and graphics. However, the manual data-input into spreadsheets is a possible source of error. Although considerable care was taken, it is possible that errors may have been introduced. As an additional precaution, however, the higher analytical results were rechecked with the BRC reports.

The BRC, at different times and locations, sampled the following environmental media for radionuclides or other radiation measurements:

- air
- milk
- sediment
- soil
- crops
- vegetation
- drinking water
- groundwater
- surface water

Discussions about each environmental media are provided in Sections 4 through 10. Radionuclides and radiation measurements that were reported included:

- Alpha Radiation
- Beta Radiation
- Plutonium-239 (^{239}Pu)
- Radium-226 (^{226}Ra)
- Tritium (^3H)
- Uranium-234 (^{234}U)
- Uranium-235 (^{235}U)
- Uranium-238 (^{238}U)

Sample locations are provided in Appendix A. Selected summary charts for some of the BRC monitoring data are presented in Appendix B.

The following table identifies the types of radiation monitoring conducted for various environmental media. Monitoring for some media or locations during some years, however, was represented by only a few samples or locations.

Table 1. Years radionuclides or radiation were monitored by the BRC for each environmental media around the Pantex Site for the years 1993 through 2003.

Media	Alpha	Beta	^{239}Pu	^{226}Ra	^3H	^{234}U	^{235}U	^{238}U
Air	—	—	93-03	93-03	—	93-03	93-03	93-03
Crops	93-94	93-94	93-95, 97-01	93-95, 97-01	93-95, 97-01	93-95, 97-01	93-95, 97-01	93-95, 97-01
Milk	—	—	93-01	93-01	—	93-01	93-01	93-01
Sediment	93-95	93-95	93-03	93-03	93-98, 00-03	93-03	93-03	93-03
Soil	93-95	93-95	93-03	93-03	93-94	93-03	93-03	93-03
Vegetation	93-94	93-94	93-03	93-03	93-02	93-03	93-03	93-03
Groundwater	93-94	93-94	93-03	93-03	93-03	93-03	93-03	93-03
Surface Water	93-94	93-94	93-03	93-03	93-03	93-03	93-03	93-03
Surface Water (Drinking)	93-94	93-94	93-03	93-03	93-03	93-03	93-03	93-03

3.0 Radionuclides and Radiation Types Monitored

Although the BRC reports do not define “Special Nuclear Material” in its summary reports, it is defined in this report as nuclear material that does not occur in significant quantities in nature. Included within this definition would be Tritium, Plutonium-239, and Uranium-235.

3.1 Alpha and Beta Radiation

Alpha and Beta radiation result from the decay series of Plutonium, Uranium, and Radium. In addition, Beta radiation is also produced from the decay of Tritium.

The EPA has set a primary drinking water standard of 15 picocuries/liter (pCi/L) for gross alpha particle activity (ATSDR website, 2005).

This drinking water standard (15 pCi/L) is equivalent to 1.5×10^{-8} uCi/mL or $1.5\text{E-}8$ uCi/mL.

Monitoring results for Alpha and Beta radiation were reported by the BRC for the years 1993-1995 from crops, vegetation, sediment, soil, and water samples. No results were reported for Alpha or Beta in air or milk.

The following tables 1 and 2 summarize the results for Alpha and Beta radiation as reported by the BRC in uCi/mL. The EPA Drinking Water Standards for Gross Alpha activity is 15 pCi/L (1.5×10^{-8} uCi/mL) and for Gross Beta activity 4 millirems/year.

No explanations or rationales were found in the summary reports as to why the BRC monitored Alpha and Beta radiation at Pantex, stopped monitoring Alpha and Beta radiation after only a brief period, and did not monitor Alpha or Beta radiation in air or milk.

Table 2. Alpha radiation – Numbers of locations and samples and summary of results for environmental media monitored for Alpha Radiation. Results for water samples are in microcuries/milliliter (uCi/mL); all other media results are reported in uCi/gram(g).

Environmental Media	Number Sampling Locations	Number of Samples	# of Results BD	Minimum	Maximum	Average
Crop	1	4	4	—	—	—
Sediment	4	10	7	1.3E-5	2.9E-5	2.1E-5
Soil	9	34	17	7.4E-6	2.2E-5	1.35E-5
Vegetation	9	19	18	2.5E-6	2.5E-6	2.5E-6
Groundwater	2	15	0	4.9E-9	1.0E-8	8.19E-9
Surface Water	2	7	3	3.4E-9	1.4E-8	8.58E-9
Surface Water (Drinking)	2	15	2	2.7E-9	1.6E-8	7.27E-9

BD = results reported as “below detection” for the analysis.

Note: Results from water samples that exceed $1.5\text{E-}8$ uCi/mL or 15 pCi/mL, exceed the Drinking Water Standard.

Table 3. Beta Radiation – Numbers of locations and samples and summary of results for environmental media monitored for Beta Radiation. Results for water samples are in uCi/mL; all other samples are reported in uCi/g.

Environmental Media	Number Sampling Locations	Number of Samples	# of Results BD	Minimum	Maximum	Average
Crop	1	4	0	4.5E-6	3.3E-5	2.01E-5
Sediment	4	10	0	1.6E-5	3.4E-5	2.35E-5
Soil	9	34	0	1.9E-5	3.5E-5	2.6E-5
Vegetation	9	19	0	1.3E-5	4.8E-5	2.9E-5
Groundwater	2	15	0	7E-9	1.1E-8	8.4E-9
Surface Water	2	7	0	4.3E-9	3.4E-8	1.7E-8
Surface Water (Drinking)	2	15	1	6E-9	2E-8	9.4E-9

BD = results reported as “below detection” for the analysis.

3.2 Tritium

Tritium is a radioactive isotope of hydrogen that has one proton and two neutrons. It has a half-life of 12.3 years and emits low-energy beta particles and, therefore, is not an external radiation hazard. However, when Tritium is ingested or inhaled it may pose an internal hazard.

Tritium is produced in nuclear accelerators and is used to enhance the explosive yield of thermonuclear weapons.

Cell One Incident, May 1989

One important source of community concern has been Tritium. An unplanned release of Tritium gas took place on May 17, 1989, at Pantex in its Cell One. This unplanned event was followed with venting the Tritium gas to the atmosphere to clear the contaminated Cell One of the contamination. According to public presentations by Pantex representatives in the past, the venting operations occurred over a period of years; however, the periodicity, seasonality, or precision of control exercised by Pantex in its subsequent venting of Tritium from Cell One to the atmosphere is not publicly known. Pantex operates an air station (PA-AR-06) near Cell One, although the effectiveness of the station to record Tritium in air emissions varies with changing wind directions and

speed, especially since the monitor is positioned near the ground surface.

Of the 29 sample results reported for PA-AR-06 following the Cell One incident on May 17, the first sample result (23,360 pCi/L) to suggest an environmental impact to air is from June 14. Prior to the incident, the May 16 sample result was reported as 43 pCi/L. Immediately following the incident, sample results for May 23, May 30, and June 6 were reported as 296 pCi/L, 1,174 pCi/L, and 126 pCi/L, respectively. The highest measurement of Tritium was reported in a sample taken later that year on November 21 (23,842 pCi/L). This information is from the Site Environmental Report for 1990 (MHSM, 1991).

The maximum Tritium concentrations reported by Pantex in its Annual Site Environmental reports for years 1989 through 2003 are provided in Table 4.

Table 4. Maximum concentrations and annual averages of Tritium in air for sampling location PA-AR-06, as reported in Annual Site Environmental reports by the Pantex Plant.

Year	Sample Location #	Maximum reported values in uCi/mL ⁴	+/- Errors in uCi/mL	Maximum value converted to pCi/L
1989	PA-AR-06	23842 x 10 ⁻⁹	1589.5	23,842.00
1990	PA-AR-06	11188.4 x 10 ⁻⁹	310.8	11,188.00
1991	PA-AR-06	22500 x 10 ⁻¹³	281	2.25
1992	PA-AR-06	6109.5 x 10 ⁻¹³	368.79	0.61
1993	PA-AR-06	5 x 10 ⁻¹⁰	<i>not reported</i>	0.50
1994	PA-AR-06	0.00000000056	<i>not reported</i>	0.56
1995	PA-AR-06	3773 x 10 ⁻¹³	42.9	0.37
1996	PA-AR-06	1398 x 10 ⁻¹³	35.2	0.14
1997	PA-AR-06	1843 x 10 ⁻¹³	57.91	0.18
1998	PA-AR-06	2431 x 10 ⁻¹³	507.75	0.24
1999	PA-AR-06 ¹	802.5 x 10 ⁻¹³	60.97	0.08
2000	PA-AR-06 ²	537.55 x 10 ⁻¹³	105.4	0.05
2001	PA-AR-06	118.6 x 10 ⁻¹³	24.79	0.01
2002	on-site, not identified ³	108.4 x 10 ⁻¹³	14.74	0.01
2003	on-site, not identified	207.9 x 10 ⁻¹³	21.72	0.02

¹Results from on-site (PA-AR-07) air sample exceeded PA-AR-06 at 821.95 x 10⁻¹³ +/- 167.81 (1999) = 0.08 pCi/L.

²Results from fenceline (FL-AR-06) air sample exceeded PA-AR-06 at 2621 x 10⁻¹³ +/- 18.98 (1999) = 0.26 pCi/L.

³Results from off-site (OA-AR-06) air sample exceeded PA-AR-06 at 2769.21 x 10⁻¹³ +/- 287.46 (2000) = 0.27 pCi/L.

⁴Results from off-site (location unidentified) air sample exceeded PA-AR-06 at 135.4 x 10⁻¹³ +/- 18.48 (2002) = 0.01 pCi/L.

⁴The above maximum values for years 1996, 1997, and 1998 were reported as Ci/mL (rather than uCi/mL) in the texts of the relative ASERs, which conflicted with the data used above from the pages referenced below.

Sources of Information: Pantex Plant Annual Site Environmental reports for years 1990 – 2003: 1990 – p. 36; 1991 – p. 4-15; 1992 – p. 4-9; 1993 – p. 5-7; 1994 – p. 8-12; 1995 – p. Chapter 8, p. 8; 1996 – p. 73; 1997 – p. 5-6; 1998 – p. 5-6; 1999 – p. 5-8; 2000 – p. 5-8; 2001 – p. 5-8; 2002 – pp. 5-6 and 5-7; 2003 – p. 5-6. Complete citations are provided in the References Cited section later in this report.

In several of its Annual Site Environmental reports, Pantex explains its higher Tritium sample results at PA-AR-06 to reflect fugitive emissions from residual contamination in the Vicinity of Cell 12-44-1.

In its most recent published report, Pantex stated that its Tritium measurements in air “continue a relative downward trend from those measured during the first few years after the 1989 release near this location” of PA-AR-06 (BWXT, 2004).

The fact that Pantex air sample results for Tritium from a fenceline (1999) and off-site (2000 and 2002) exceeded the maximum results for PA-AR-06 for those years – even though off-site monitors are few and far between – illustrates one of the challenges or difficulties for ad-

equately monitoring air contaminants from an industrial source. Since 1997, Pantex has operated four (4) off-site air sampling locations – three located northeast and one east of Pantex. As so few samples are taken, the likelihood of capturing the maximum contaminant concentrations that existed off-site is diminished. On days in which wind patterns are not in the direction of these four locations, then contaminant plumes will not be monitored. Air monitoring by Pantex for the years 1999, 2000, and 2002 substantiate that the highest contaminant plumes in air may not be on-site, at least at the location of its air monitors.

In spite of community concerns about Tritium, no analytical results for Tritium monitoring were reported from samples of air or milk by the BRC.

3.3 Plutonium-239

Plutonium-239 is a radioactive element that does not occur naturally to any significant extent but is produced in nuclear reactors (ATSDR website, 2005). The most common Plutonium isotopes are Pu-238 and Pu-239. A major source of Plutonium in the environment is nuclear weapons testing. Plutonium undergoes radioactive decay, producing Alpha, Beta and Gamma radiation in the process. Low levels of Plutonium may be absorbed by plants. Plutonium pits are stored at the Pantex Plant.

All 2588 samples for which analyses were reported included results for Plutonium-239. However, all but one of the results were reported to be below the laboratory's detection limits.

3.4 Radium-226

Radium-226 and Radium-228 are formed when Uranium and Thorium break down, or decay. The decay series of which Radium is a part produces Alpha, Beta and Gamma radiation. Until the 1960s, Radium was used in luminous paints for watch and clock dials. Radium may be found in soil and absorbed by plants, in water where it may concentrate in fish and other aquatic organisms, and in the air.

The EPA has also set a soil concentration limit for Radium-226 in Uranium and Thorium tailings of 5 pCi/g in the first 15 cm of soil. The EPA has set a drinking water limit of 5 pCi/L for Radium-226 and Radium-228 combined (ATSDR website, June 2005). Although Radium-226 was monitored by the BRC, no results were provided for Radium-228.

Radium analyses were determined by either gamma-spectroscopy or chemical analysis procedures.

4.0 Air

Monitoring results were reported for Plutonium-239, Radium-226, Uranium-234, Uranium-235, and Uranium-238. No analytical results were found in the BRC report summaries for Alpha or Beta radiation or Tritium in air samples.

Sampling Locations and Monitoring Intervals for Air Samples

All of the BRC's air monitoring stations were located on-site at Pantex (Appendix A).

3.5 Uranium-234, 235, and 238

Natural Uranium consists of three isotopes – ^{234}U , ^{235}U , and ^{238}U . The decay of Uranium isotopes produces Alpha, Beta and Gamma radiation. The most abundant natural isotope of Uranium is ^{238}U (99.28%) which has a half-life of about 4.5 billion years. Uranium-238 decays in a series of steps to Radium-226 and Uranium-234 among others, and eventually to the stable isotope Lead-206. The proportion of Uranium-234 in nature is about 0.0057% and that of Uranium-235 about 0.72%, by weight. Uranium-235 is the isotope of Uranium used in nuclear weapons.

Uranium is chemically toxic at high concentrations and can cause damage to internal organs – especially the kidneys. The EPA has promulgated a DWS of 30 ug/L as of December 8, 2003, for Uranium.

Uranium, a heavy metal, is also a special nuclear material of concern at the Pantex Plant. Unlike Plutonium, Uranium is also a naturally-occurring element. However, higher concentrations of ^{234}U and ^{238}U can result from environmental releases.

Analyses for Uranium were reported in the summaries to have been conducted by alpha- and gamma-spectroscopy.

The Station numbers, location descriptions, and time intervals in which air was monitored are:

- 101 – east of Playa One (January 1993 – August 1997)
- 102 – south of Zone 11 (January 1993 – August 1997)
- 103 – southwest of Zone 4 (January 1993 – August 1995)
- 104 & 104Q – south of the Burning Grounds (January 1993 – present)
- 105 – north of the Burning Grounds (January 1993 – present)
- 106 – south of the northwest corner of the Plant-site (November 1995-August 1997)
- 104T – location not described (1999-June 2000)
- 105T – location not described (1999)

The following table provides the distribution of samples with location as reported by the BRC in its summary reports.

Table 5. Time periods in which air sampling stations were used and total number of samples per year.

Locations	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
101	X	X	X	X	X						
102	X	X	X	X	X						
103	X	X	X								
104	X	X	X	X	X	X	X	X	X	X	X
104Q	X	X	X	X	X	X	X	X	X	X	X
105	X	X	X	X	X	X	X	X	X	X	X
106			X	X	X						
104T							X	X			
105T							X				
# Samples per year	338	346	324	312	249	63	77	72	54	55	60

Since August 1997, Stations 104, 104Q, and 105 are the only air stations monitored. Station 104 is located south of and 105 north of the Burning Ground. Some of the results for Radium-226 may suggest air contaminants resulting from Pantex operations at the Burning Grounds and/or the Firing Sites. However, because all other stations were removed prior to the monitoring schedule change late in 1997, no data are available for monitoring other Pantex operations or off-site. Thus, the appearance of air contaminants resulting from the Burning Ground and/or Firing Sites may be due to (an artifact of) the BRC sampling strategy.

4.1 Special Issues of Concern

Predictability of the BRC Air Monitoring Schedule

Prior to October 1997, the publicly-acknowledged BRC air monitoring schedule was to sample every 6th day. Perhaps in response to community concerns that such a schedule may influence operations at Pantex and not succeed in capturing a full picture of the community's air contaminants, the schedule was changed at that time. Thereafter, the schedule for air sampling was supposed to be more random, and, therefore, less predictable.

Changes in Detection Limits for Radium-226

Another change that has affected the results reported by the BRC, as well as the ability to interpret those results, involved monitoring for Radium-226. On or about June 1, 1998, the detection limits for Radium-226 in air were raised from about 1×10^{-15} to as high as 2×10^{-14} uCi/L – a 20-fold increase. Although this change may have been for good reason, no explanation was provided in the annual summary (BRC 1999). The net effect of the change was that numerical results reported in previous samples were reported as “below detection” in future samples.

4.2 Alpha and Beta Radiation and Tritium

Although Beta radiation results from Tritium decay, a community concern, Alpha and Beta radiation and Tritium were not reported to have been monitored in air by the BRC.

4.3 Radium-226

The following table summarizes the data for Radium-226 in air.

Table 6. Radium-226 (in uCi/mL) in air by location, showing ranges and average values for measurements reported to have exceeded detection limits.

Location #	# Samples >DL	Minimum	Maximum	Average
101	263	1E-16	5.1E-15	4.97E-16
102	263	1.4E-16	3.9E-15	5.06E-16
103	147	1.6E-16	1E-15	4.4E-16
104	283	5.3E-17	3.2E-14	1.3E-15
104Q	259	1.4E-16	1.9E-14	7.21E-16
105	291	1E-16	2.7E-14	8.95E-16
105T*	1	1E-14	1E-14	1E-14
106	100	3.7E-16	1.1E-15	6.22E-16
140Q**	1	4.4E-16	4.4E-16	4.4E-16*
All Data	1608	5.3E-17	3.2E-14	7.56E-16

*only one result was reported for this station.

**Location unknown.

4.4 Uranium-234, 235, and 238

No results for ^{235}U were reported as above detection limits. A summary of results for ^{234}U and ^{238}U are provided in the following table. The maximum values reported for both ^{234}U and ^{238}U were from samples collected from station 105.

Table 7. SummaryData for Uranium-234 and Uranium-238 (in uCi/mL) in air.

Radionuclide	# Samples >DL	Minimum	Maximum	Average
Uranium-234	679	1.8 E-16	1.7 E-15	6.53 E-16
Uranium-238	679	2 E-16	5 E-4*	7.36 E-7

* Next highest measurement was 1.7 E-15, also from Station 105.

4.5 Resulting Questions or Concerns – Air Monitoring

No explanations or rationales were found in the summary reports as to why the BRC

- selected its monitoring stations;
- collected samples on a predictable 6-day sampling schedule prior to October 1997;
- ended monitoring specific stations;
- did not monitor Alpha or Beta radiation in air;
- did not monitor Tritium, given the acknowledged Pantex releases, both unplanned and planned, of Tritium to the atmosphere;
- changed detection limits mid-year 1998, to a much higher detection limit for Radium-226.

5.0 Crops

The summary BRC reports provided neither the type of crop or parts of the plants sampled. With crop rotations common, the crop may have included different crops at different sampling times. Because different crops would be expected to uptake contaminants differently, and different parts of the crops become part of the human food chain, this information should have been included in the BRC reports.

The length of time the crop sampled had been growing would also be expected to influence the results. Identification of the crops monitored would allow some interpretation as to the age of the plants that were sampled. Fourteen of the 17 crop samples were collected during the months of April and October, one sample was collected in January; and two in July of the years monitored.

Sampling Locations for Crop Samples

The BRC reported sampling results for 17 samples collected from a single location located just east of the northern part of the Pantex Plant-site (see Appendix A).

It was not reported why samples were not collected during 1996, 2002, and 2003. It was also not explained why commercial crops grown on-site, such as adjacent to the Burning Grounds, were not included in the BRC sampling strategy.

Table 8. Number of crop samples collected and analyzed per year.

Location	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
25	2	3	2	0	3	1	3	2	1	0	0	17

5.1 Alpha and Beta Radiation

Of the 17 samples collected, only the first 4 samples were analyzed for Alpha and Beta radiation. No measurements were reported to exceed the detection limits for Alpha radiation. No samples collected thereafter were reported to have been analyzed for either Alpha or Beta radiation, and no explanation for ending this monitoring was reported – although the results from monitoring Beta radiation ended on an upward trend.

5.2 Tritium

All results for monitoring Tritium in crop samples were reported by the BRC to be below detection limits.

5.3 Radium-226 and Uranium-234, 235, and 238

With the exception of the concentrations reported for Beta radiation (Table 3 above), only three other samples resulted in detections above detection limits and are provided in Table 9.

Table 9. Other values reported to be above detection-levels reported from crop samples.

Date	Radionuclide Type	Measurement (uCi/g)
April 19, 1995	Radium-226	1E-6
April 19, 1995	Uranium-238	9E-7
April 20, 1998	Uranium-238	9E-7

Note: 1×10^{-9} uCi/g = 1 pCi/kg

5.4 Resulting Questions or Concerns – Crop Monitoring

No explanations or rationales were found in the summary reports as to why the BRC

- did not reveal which crops were monitored;
- selected only one location to monitor;
- selected the months of April and October for the majority of its crop sampling;
- did not monitor crops during years 1996, 2002, and 2003;
- monitored Beta radiation for only a brief time, even though the few results obtained ended on an upward trend;
- did not monitor any on-site commercial crops, although those crops enter the public realm through the marketplace.

6.0 Milk

Sampling Locations and Monitoring Intervals for Milk Samples

The BRC sampled and analyzed 88 milk samples, which were collected from six (6) off-site locations (Appendix A). Three of the sample locations are located more than 10 miles from Pantex, while three are within 3 ½ miles. One location (34), would be expected to be downwind of Pantex operations much of the time, based on the regional prevailing winds.

Locations for milk sampling included

- 31 – at or near Boys Ranch (northwest of Amarillo)
- 32 – east of Canyon (south of Amarillo)
- 33 – north of Canyon (south of Amarillo)
- 34 – household approximately 3+ miles northeast of Pantex
- 35 – household west-northwest of, and near, Pantex
- 36 – household west of, and near, Pantex

Table 10. Number of Milk Samples by location and year for Uranium-234 and Uranium-238.

Locations	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total Samples
31	3	4	4	4	4	4	4	1	1			29
32	4											4
33		3	4	4	4	4	2	1				22
34	3	4	4	4	4	4	3	1	1			28
35	1	1										2
36	1	1		1								3
Totals	12	13	12	13	12	12	9	3	2	0	0	88

6.1 Alpha and Beta Radiation and Tritium

Although Beta radiation results from Tritium decay, a community concern, neither Beta Radiation or Tritium were reported to have been monitored in milk by the BRC.

6.2 Radium-226

The BRC results for monitoring Radium-226 in milk are provided in Table 11 below.

Table 11. Analyses of Radium-226 in Milk (in uCi/mL).

Location #	Number of Samples	Number of Reported Values*	Minimum	Maximum	Average
31	29	28	2E-10	1E-9	6.07E-10
32	4	4	8E-10	1.1E-9	5.75E-10
33	22	22	4E-10	1E-9	6.12E-10
34	28	28	3E-10	1.3E-9	6.46E-10
35	2	2	4E-10	4E-10	4E-10
36	3	3	4E-10	7E-10	6E-10
Total	88	87	2E-10	1.3E-9	6.26E-10

* One sample was reported to be below the detection limit.

The only location that exceeded the overall mean was Location #34, located approximately 3.5 miles northeast of Pantex. The highest measurement (1.30E-9 uCi/ml, or 1.3 pCi/L) was also recorded for a sample from this location.

6.3 Uranium-234, 235, and 238

Analyses of four of the 88 samples resulted in three detections each of Uranium-234 and Uranium-238. However, all of these results were from samples distant (more than 10 miles) to Pantex. All results for Uranium near Pantex were below detection.

There were no detections reported for Uranium-235 at any location.

6.4 Resulting Questions or Concerns – Milk Monitoring

No explanations or rationales were found in the summary reports as to why the BRC

- did not monitor Alpha or Beta radiation or Tritium in milk, even though Tritium contamination is a community concern;
- chose to collect milk samples from 3 sites so distant from Pantex;
- did not conduct a more concentrated effort nearer to Pantex, even though the maximum individual result and average for Radium-226 were from the single location within 3 ½ miles of Pantex in a, generally, downwind direction;
- appears to have stopped monitoring milk after 2001.

7.0 Vegetation

The summary BRC reports provided neither the species of crop or parts of the plants sampled. Because species of plants uptake metals differentially and metals may concentrate differently in various parts of the plants, it is important that this information be provided in the reports.

Sampling Locations for Vegetation Samples

The BRC reported results for 101 vegetation samples collected from 12 locations (Appendix A) during 1993-2003. Four of the off-site locations are on Texas Tech Research Farm south of Pantex and the fifth about 3 miles northeast of Pantex in the predominantly downwind direction. Seven of the locations are on-site at Pantex.

The BRC used the same sampling locations for vegetation and soils. Conflicting information about locations 8 and 19 are provided in Appendix A.

The numbers and descriptions for each sampling location were

- 4 – about 3 miles northeast of the Pantex northeast boundary, off-site
- 8 – intersection of Hwy 60 and 683, off-site
- 14 – north-northeast boundary of Pantex, on-site
- 16 – north of the Burning Ground, on-site
- 18 – east of Playa 5, off-site
- 19 – intersection of Hwy 60 and 2373, off-site
- 20 – eastern boundary near Pump'n Treat system, on-site
- 21 – boundary at northeast corner, on-site
- 26 – near west gate, on-site
- 37 – near east gate, on-site
- 38 – boundary at northwest corner, on-site
- 39 – southwest boundary of Pantex with Texas Tech Research Farm, off-site

Table 12. Numbers of Vegetation samples by location and year.

Location	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Totals
4	2	2	1		2	2	2	1	1			13
8	2	1	1		1	1	1		1			8
14	1	1	1	2	1	1	1	1		1		10
16	2	1	2		2	2	1	1	1	2		14
18	1	1	1	2	1	1	1	1	1			10
19	2	1	2		2	1	1		1			10
20	1	1	1	2	1	1	1	1		1	1	11
21	2	1	2		2	2	1	1	1			12
26	1	1	1	2	1	1	1					8
37								1		1		2
38								1	1			2
39								1				1
Totals	14	10	12	8	13	12	10	9	7	5	1	101

7.1 Alpha and Beta Radiation

The BRC reported Alpha and Beta radiation monitoring results for 19 samples. A summary of results for Alpha and Beta radiation are provided in Table 2 and 3 above, respectively.

7.2 Tritium, Radium-226, and Uranium-234, 235, and 238

No values were reported above detection limits for Uranium-234 and Uranium-235. Results are summarized for Tritium, Radium-226, and Uranium-238 in Table 13 below.

Table 13. Summary of Results (in uCi/g) for Radium-226 and Uranium in Vegetation.

Radionuclide	# Detections	Minimum	Maximum	Average
Tritium	7	1 E-6	8.4 E-6	2.51 E-6
Radium-226	9	1 E-7	1.9 E-6	6.57 E-7
Uranium-238	7	1 E-7	9 E-7	5.86 E-7

Note: $1 \times 10^{-7} \text{ uCi/g} = 100 \text{ pCi/kg}$.

7.3 Resulting Questions or Concerns – Vegetation Monitoring

No explanations or rationales were found in the summary reports as to why the BRC

- did not identify the species or plant parts, describing whether it was an annual or perennial, used as samples;
- monitored Alpha and Beta radiation only briefly.

8.0 Sediment

Sediments may contain fine clay particles onto which contaminants may adsorb. An example is the Randall clay that underlies the regional playa lakes. However, no description of the sediment was provided in the reports.

Sampling Locations for Soil Samples

A total of 54 samples were collected from five locations. Four of the locations are Playa lakes on or near Pantex; one location is in Amarillo.

The BRC reported monitoring results for surface water in the same four playas, as well.

Table 14. Distribution of numbers of samples in Sediments by location and year.

Location	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Totals
12		1	1	1	1	1	1	1	1	1	1	10
15	1	1	1		1	1	1	1		1		8
22	2	4	3	4	4	2		2	1	1	1	24
23	1		1	1	1	1	1	1	1	1	2	11
28				1								1
Totals	4	6	6	7	7	5	3	5	3	4	4	54

Location 12 – northeast corner of Pantex Lake, about 2 ½ miles northeast of Pantex

Location 15 – south side of Pratt Lake, north of Pantex

Location 22 – Playa 1, onsite

Location 23 – northeast side of Playa 4

Location 28 – intersection of NE 24th and the Fritch Hwy in Amarillo

8.1 Alpha and Beta Radiation

The BRC reported Alpha and Beta radiation results for 10 samples. A summary of results for Alpha and Beta radiation are provided in Table 2 and 3 above, respectively.

8.2 Tritium

No values for Tritium were reported above detection limits for sediment samples.

8.3 Radium-226, and Uranium-234, 235, and 238

Table 15. Summary of Results (in uCi/g) for Radium-226 and Uranium in Sediments.

Radionuclide	# Detections	Minimum	Maximum	Average
Radium-226	2	2.7 E-6	2.8 E-6	2.75 E-6
Uranium-234	4	1 E-6	1.3 E-6	1.15 E-6
Uranium-238	7	1 E-6	2.2 E-6	1.3 E-6

Note: 1×10^{-6} uCi/g = 1000 pCi/kg.

8.4 Resulting Questions or Concerns – Sediments Monitoring

No information or explanations were found in the summary reports about

- sediment particle size or percent clay;
- depths at which samples were collected;
- why Alpha and Beta radiation monitoring were only briefly conducted.

9.0 Soils

Sampling Locations for Soil Samples

A total of 198 samples were collected from 13 locations (7 on-site and 6 off-site, see Appendix A). Monitoring results for vegetation samples were reported for these same locations, and descriptions of the locations are provided in that section of this review.

Table 16. Distribution of numbers of soil samples by location and year.

Location	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Totals
4	2	1	2	1	2	2	2	2	1	2	1	18
8	2	1	2	1	2	2	2	2	1	2	1	18
14	2	2	2	3	2	2	2	2	1	2	2	21
16	2	2	2	1	2	2	2	2	1	2	1	18
18	2	2	2	3	2	2	2	2	1	2	3	22
19	2	2	2	1	2	2	2	2	1	2	1	18
20	2	1	2	3	2	2	2	2	1	2	3	21
21	2	2	2	1	2	2	2	2	1	2	1	18
25				1								1
26	1	2	2	2	2	2	2					12
37								2	1	2	3	8
38								2	1	2	3	6
39								2	1	2	3	8
Totals	17	15	18	17	18	18	18	22	11	22	22	198

9.1 Alpha and Beta Radiation

The BRC reported Alpha and Beta radiation monitoring results for 34 soil samples. A summary of results for Alpha and Beta radiation are provided in Table 2 and 3 above, respectively.

9.2 Tritium

No values for Tritium were reported above detection limits for soil samples. Two samples were reported as “laboratory error.”

9.3 Radium-226 and Uranium-234, 235, and 238

The results for Radium and Uranium in soils are given in Table 17 below.

Table 17. Summary of Results for Radium-226 and Uranium in Soils (in uCi/g).

Radionuclide	# Detections	Minimum	Maximum	Average
Radium-226	135	3 E-7	4 E-6	1.92 E-6
Uranium-234	71	1 E-6	1.7 E-6	1.1 E-6
Uranium-238	126	7 E-7	5.1 E-6	1.33 E-6

Note: 10^{-6} uCi/g = 1 pCi/g

9.4 Resulting Questions or Concerns – Soils Monitoring

No information or explanations were found in the summary reports about

- soil particle size;
- depths at which samples were collected;
- why Alpha and Beta radiation monitoring were only briefly conducted.

10.0 Water – Surface, Ground, and Drinking

Sampling Locations for Water Samples

A total of 139 water samples in four separate classifications were reported. The seven sampling locations (see Appendix A) for which water samples were reported included:

- 12 – Pantex Lake
- 15 – Pratt Lake
- 22 – Playa One
- 23 – Playa Four
- 24 – South Osage Street, near 34th, in Amarillo
- 27 – City of Amarillo Lift Station, about 2 miles north of Pantex
- 28 – Intersection of NE 24th and Fritch Hwy, Amarillo
- 30 – west side of city of Panhandle

The BRC summary reports present its analytical results for water samples grouped in three classifications, although the terminology varies somewhat between years:

- Water – Surface (Drink) or Water – Drinking
- Water – Ground
- Water – Surface

However, the assignment of samples from specific locations to categories was inconsistent between years of the summary reports. For example, samples from location numbers 24 and 28 were assigned to Surface Drinking water for years 1993-1998; however, samples from these two locations were assigned to Surface water thereafter. Similarly, samples from location number 30 were assigned to Surface-Groundwater for years 1993-2002, but to Surface Drinking water for 2003. For this reason, results provided in Table 19 are summarized for all results reported by BRC in one group of water samples.

Table 18. Assignments of water samples to Drinking (DW), Ground (G), or Surface Water (S) according to location and year.

Location	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
12			S		S	S	S	S			
15			S		S		S	S			
22	S	S	S	S	S	S		S	S	S	S
23	S	S	S	S	S		S	S	S		
24	DW	DW	DW	DW	DW	DW	S	S	S	S	S
27	G	G	G	G	G	G	G	G	G	G	G
28	DW	DW	DW	DW	DW	DW	S				
30	G	G	G	G	G	G	G	G	G	G	DW

10.1 Alpha and Beta Radiation

The BRC reported Alpha and Beta radiation monitoring results for 37 samples. A summary of results for Alpha and Beta radiation are provided in Table 2 and 3 above, respectively.

10.2 Tritium

No values for Tritium were reported above detection limits for water samples.

10.3 Radium-226 and Uranium-234, 235, and 238

The reported concentrations of Uranium and Radium isotopes in water are summarized in Table 19.

Table 19. Radium-226 and Uranium-234 and -238 in Water Samples (uCi/mL)

Radionuclide	Minimum Value	Maximum Value
Radium-226	3.0 E-10	8.4 E-8
Uranium-234	1.2 E-9	1.1 E-8
Uranium-238	1.0 E-9	9.2 E-8

Note: 10^{-8} uCi/mL = 10 pCi/L

The EPA has issued a DWS for Radium-226 and Radium-228 in combination (set at 5 pCi/L). Although the BRC reported values only for Radium-226, and not for Radium-228, some reported values for Radium-226 exceed the EPA standard by themselves. Analyses reported by Pantex indicate that Radium-228 is more abundant than Radium-226 (BPx-MHSM, 1998, Table 6.2, p. 6-9). However, the natural abundance of Radium isotopes is such that more than 99% of naturally-occurring Radium is of the isotope Radium-226 and less than 1% is Radium-228.

Table 20. Comparison of values reported for Radium-226 in water samples to the primary Drinking Water Standard.

Location	Reported as Water Type	Date of Sample	Reported Value in uCi/mL	Value Converted to pCi/L	Primary DWS for $^{226}\text{Ra} + ^{228}\text{Ra}$ 5 pCi/L
22	Surface	July 1998	4.3 E-8	43	Exceeds
22	Surface	Oct 1997	5.1 E-8	51	Exceeds
27	Ground	Oct 2003	6.2 E-8	62	Exceeds
24	Surface	Oct 2003	7.6 E-8	76	Exceeds
24	Surface	July 2003	8.4 E-8	84	Exceeds
24	Drinking	Oct 1997	1.0 E-9	1	
24	Drinking	Jan 1997	1.8 E-9	1.8	

Although a number of samples were reported as below the detection limit for Radium-226, in many cases the reported detection limit exceeded the DWS. This was the case for 175 water samples that were reported to be “below detection” for Radium-226 for 1993-2003. The range of detection limits for these samples ranged from $1.9\text{E-}8$ to $1.35\text{E-}7$ uCi/mL, which converts to the range of 19 – 135 pCi/L ^{226}Ra for comparison to the 5 pCi/L DWS (^{226}Ra and ^{228}Ra , combined).

10.4 Resulting Questions or Concerns – Water Monitoring

No explanations or rationales were found in the summary reports as to why the BRC

- reported results for three locations under different categories in different years;
- monitored Alpha and Beta radiation only briefly;
- did not monitor Radium-228;
- did not discuss concerns about some of the samples exceeding the Drinking Water Standard for Radium-226 + Radium-228.

11.0 Conclusions

Considering the stated intention of the BRC Monitoring effort—to determine the presence of any special nuclear materials—it seems that the BRC published reports have left a number of questions unanswered. Most puzzling are the unexplained site-selection for sampling, timing of collecting samples, as well as changes in sampling locations. A summary of the major findings and major deficiencies, based on this review, is given in the section below.

Major Findings of this Review

1. Radium-226 values in surface water and groundwater exceed the Primary Drinking Water Standard.
2. The detection limits for Radium-226 in many instances exceed the Primary Drinking Water Standard by a factor of 10 or more.
3. Samples were not analyzed for Radium-228, even though results for Radium-226 exceed or approach the Primary Drinking Water Standard and the few analyses conducted by Pantex on both isotopes indicate that Radium-228 is more abundant than Radium-226.

Major Deficiencies in the Database

1. No clear or evident rationale for selection of sampling sites – a single off-site location was selected to monitor crops; several sites were selected to monitor milk were distant to Pantex; on-site commercial crops were not monitored.
2. Short duration of monitoring for alpha and beta radiation.
3. Failure to monitor Tritium in air and milk.
4. Failure to record species, plant parts, annual vs perennial information about crops and vegetation sampled.
5. Failure to explain changes in monitoring protocol, such as detection limits for Radium-226 in air.
6. Failure to follow-up “possible lab errors” and re-sample and re-analyze in a timely manner.
7. Inconsistencies in mapped locations for sampling locations and in classification of water samples.

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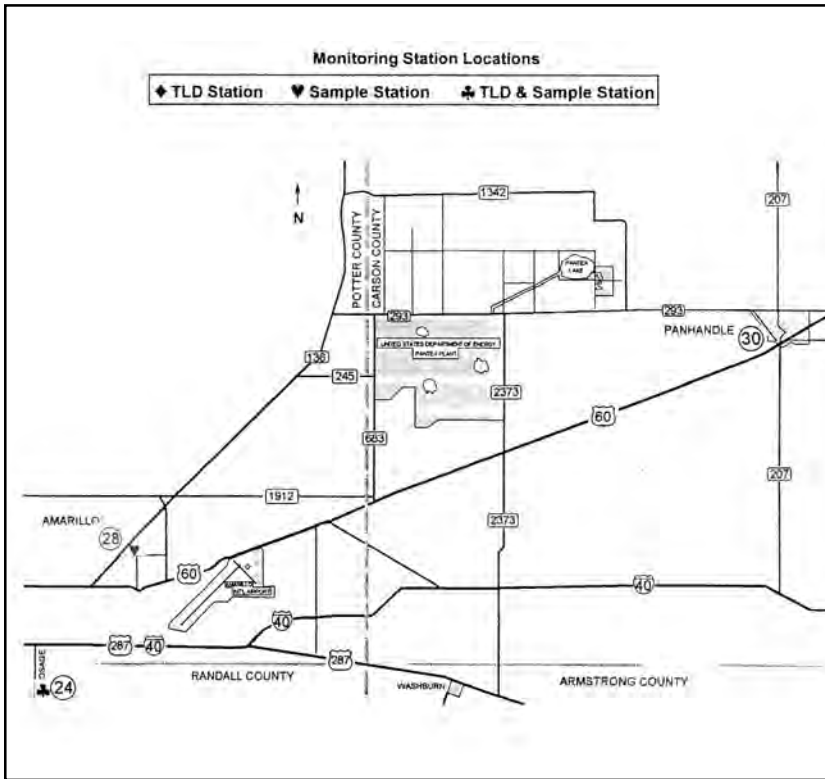
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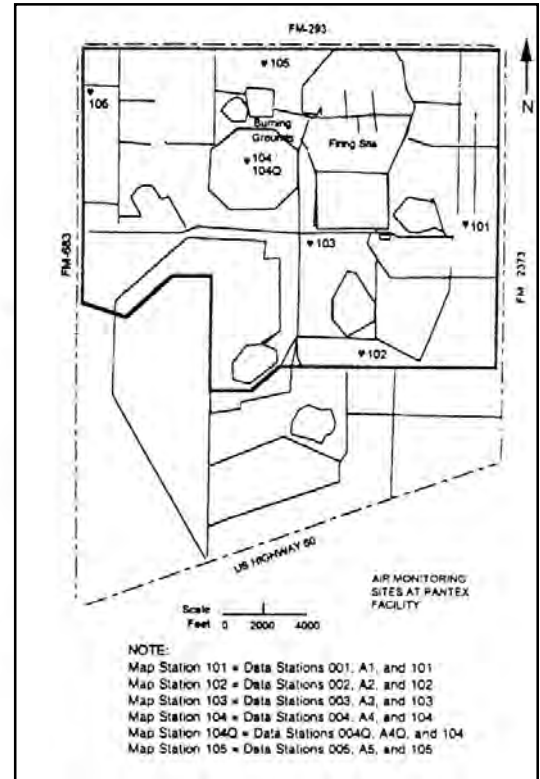
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Appendix A – Sample Location Maps



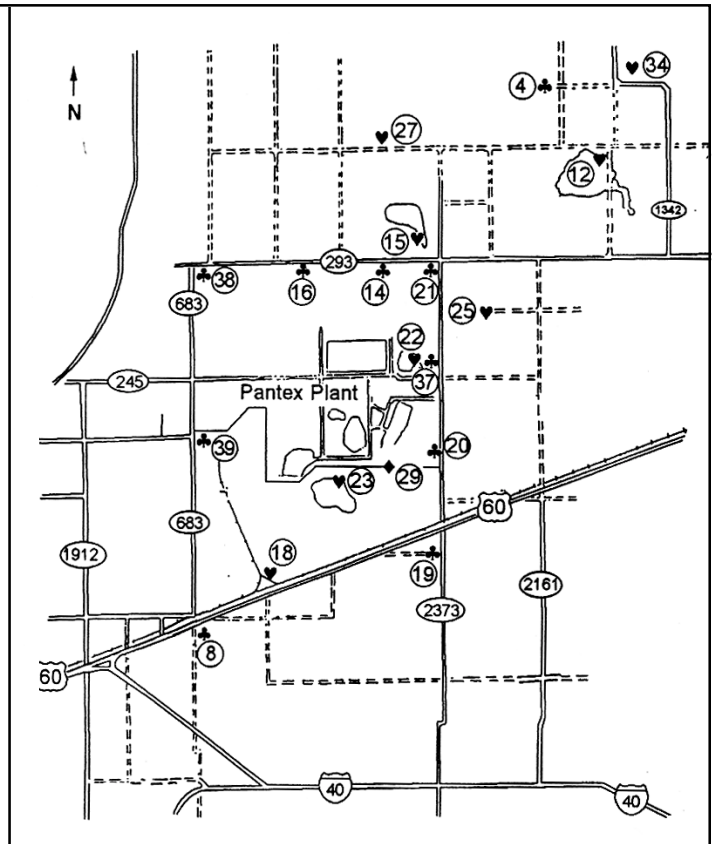
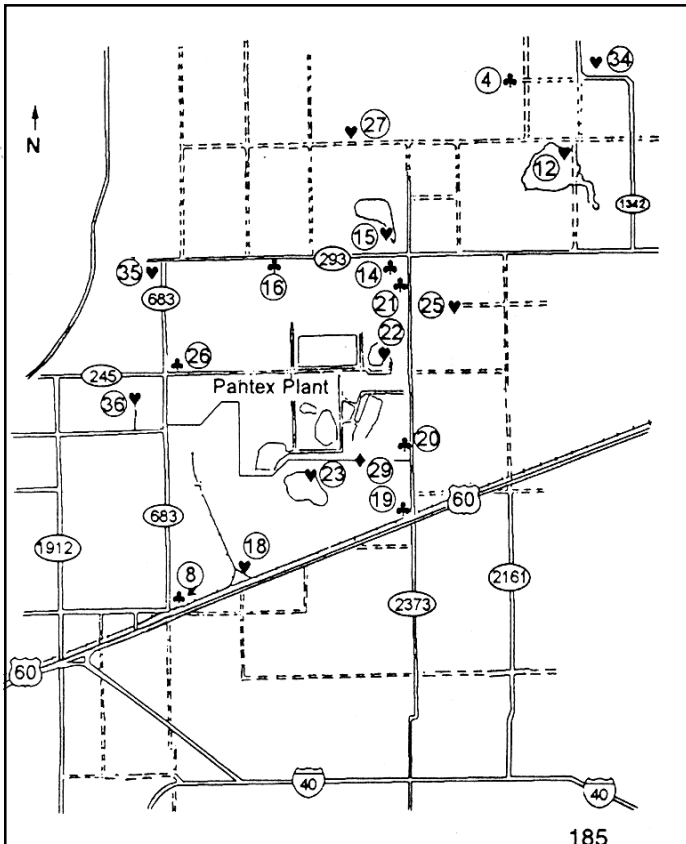
Pantex, Amarillo, and Panhandle regional map.



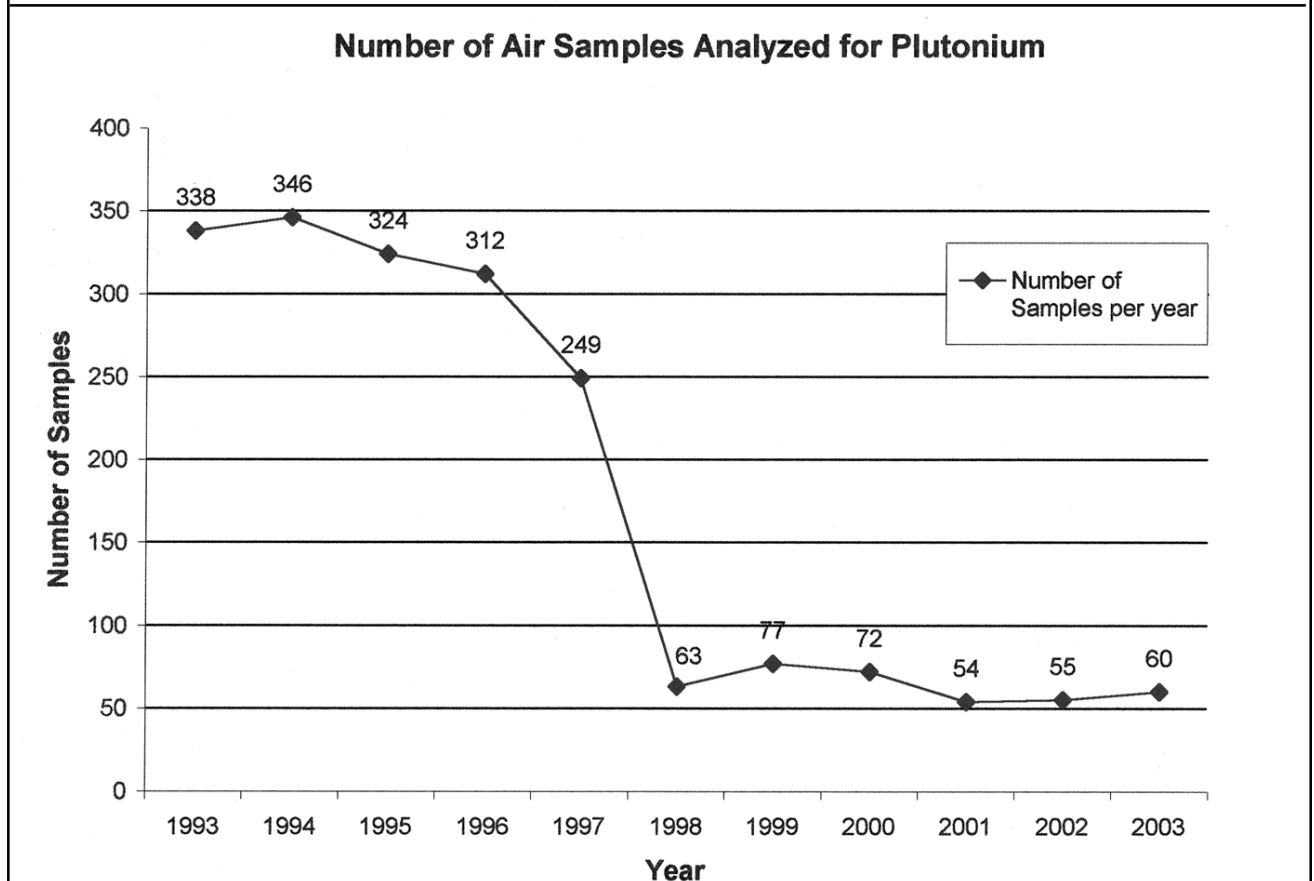
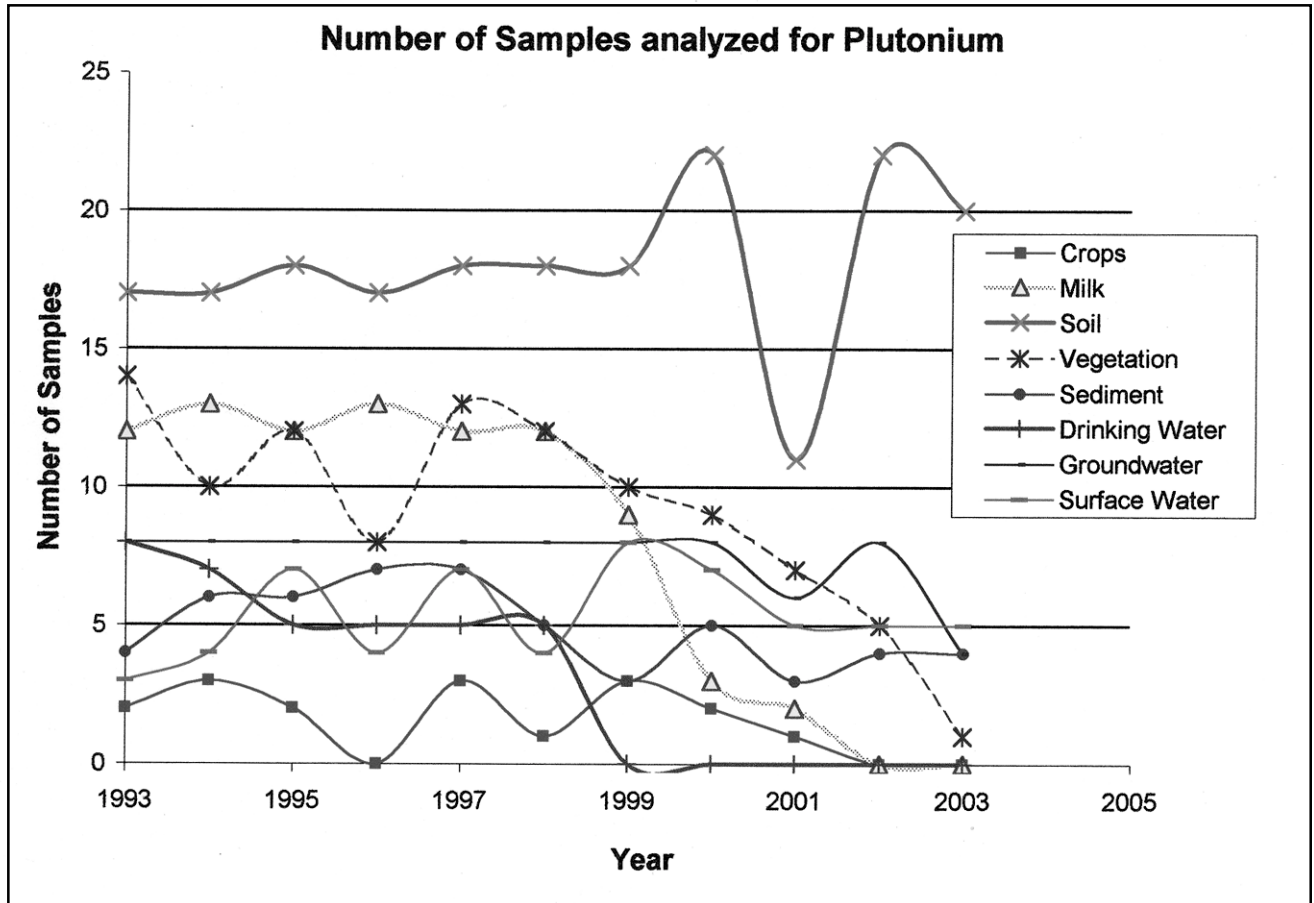
Bureau of Radiation Control air stations at Pantex.

Sample locations for 1993-1998.
Maps for 2000 through 2002 were not available.

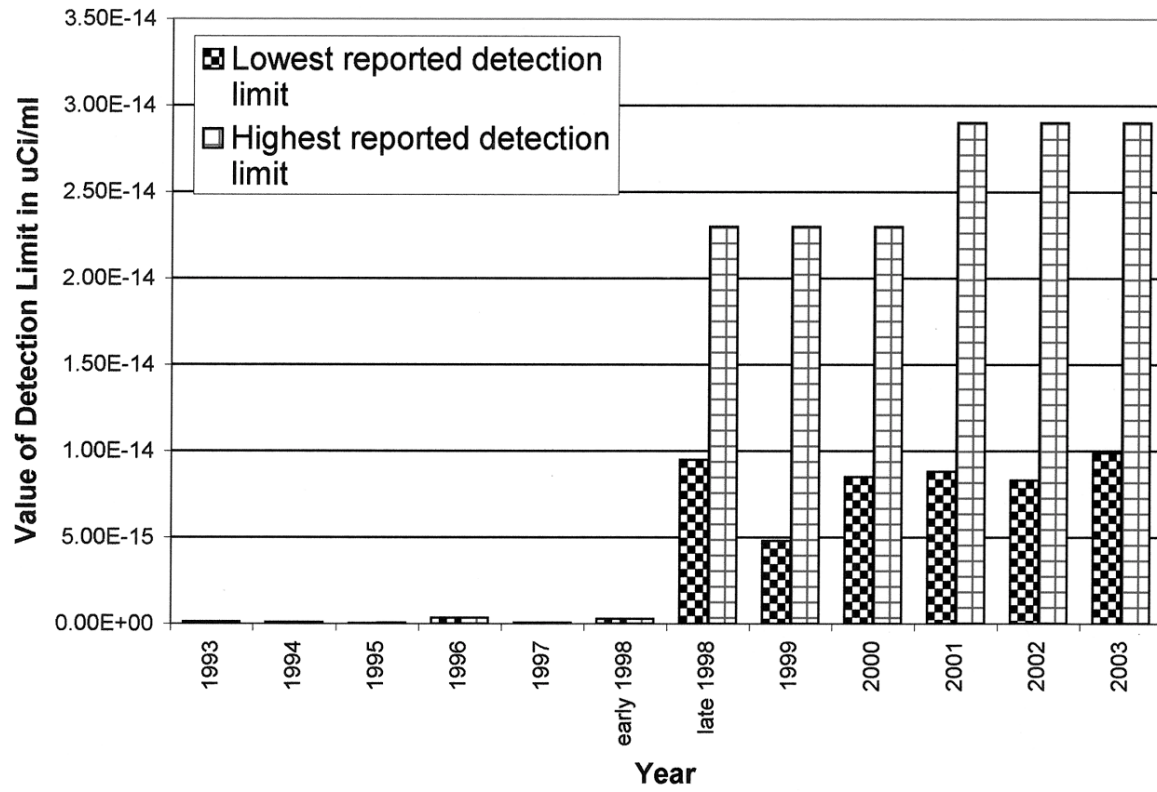
Sample locations for 1999 and 2003. Note that some locations vary from the 1993-1998 map.



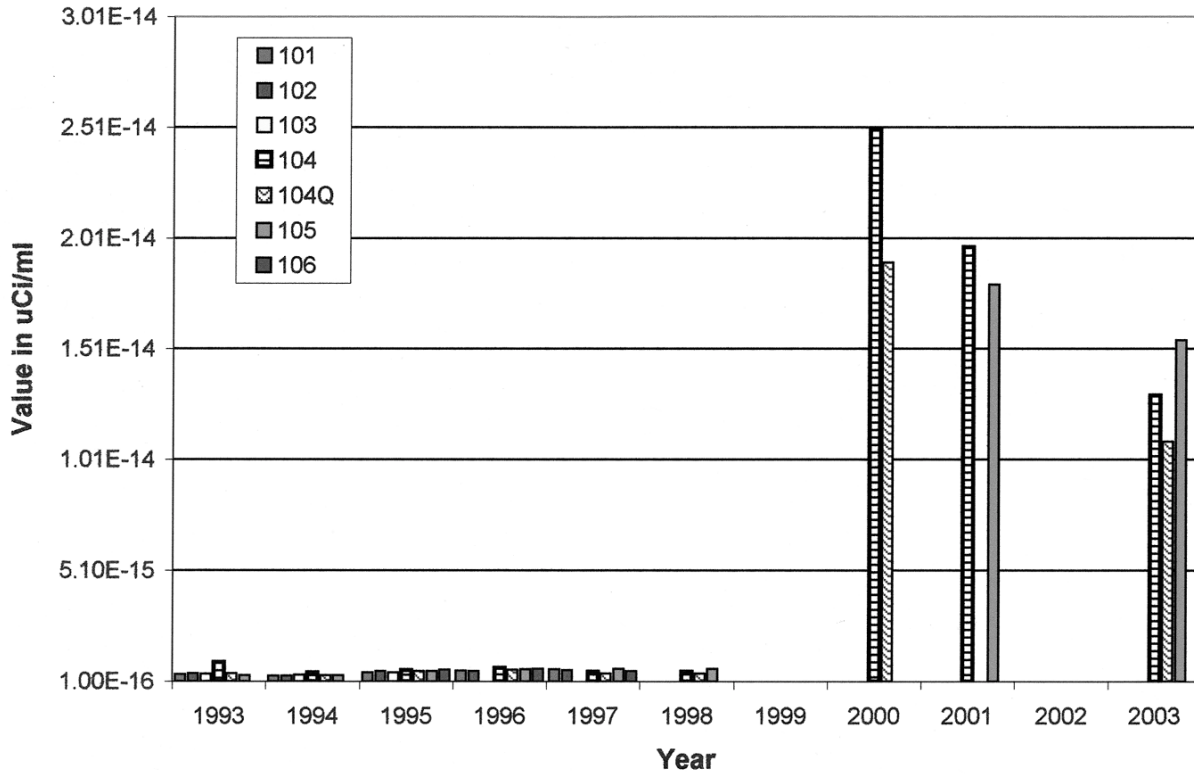
Appendix B – Selected Graphs and Charts



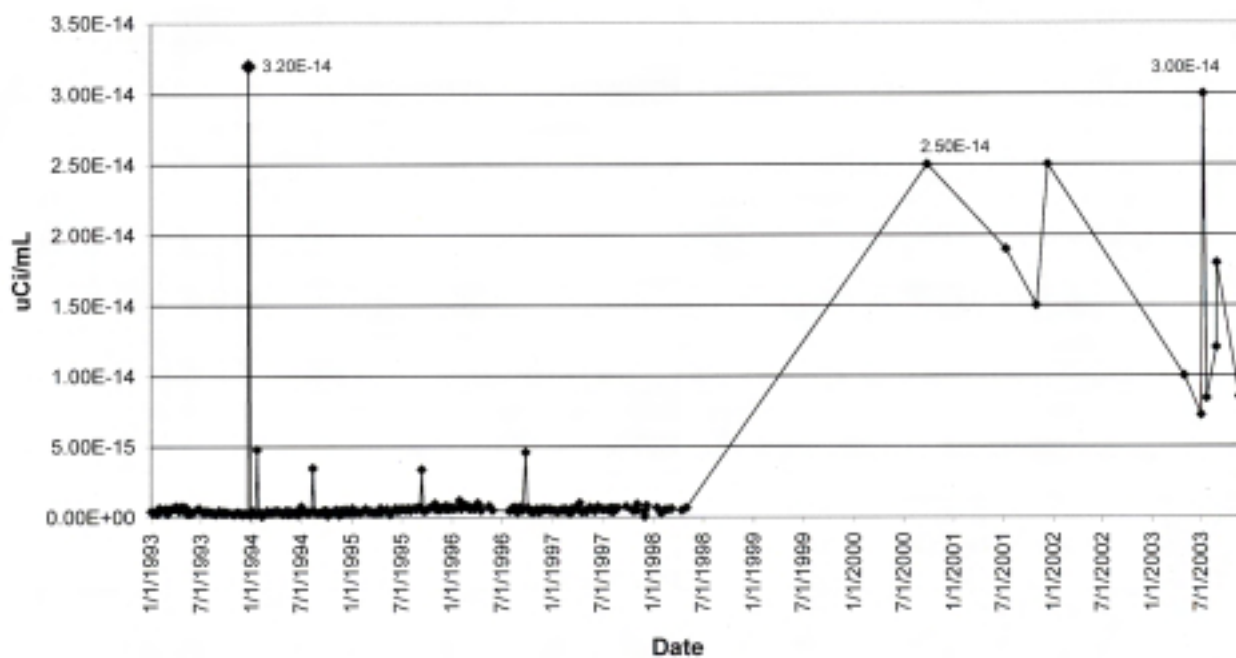
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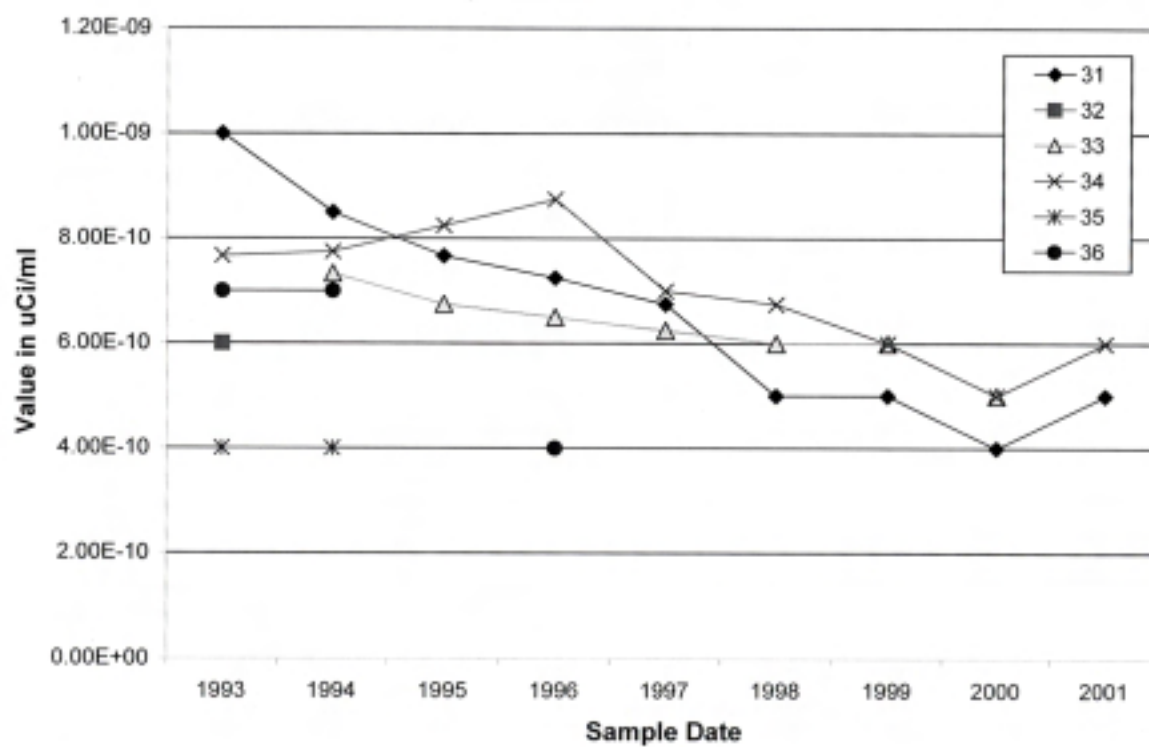
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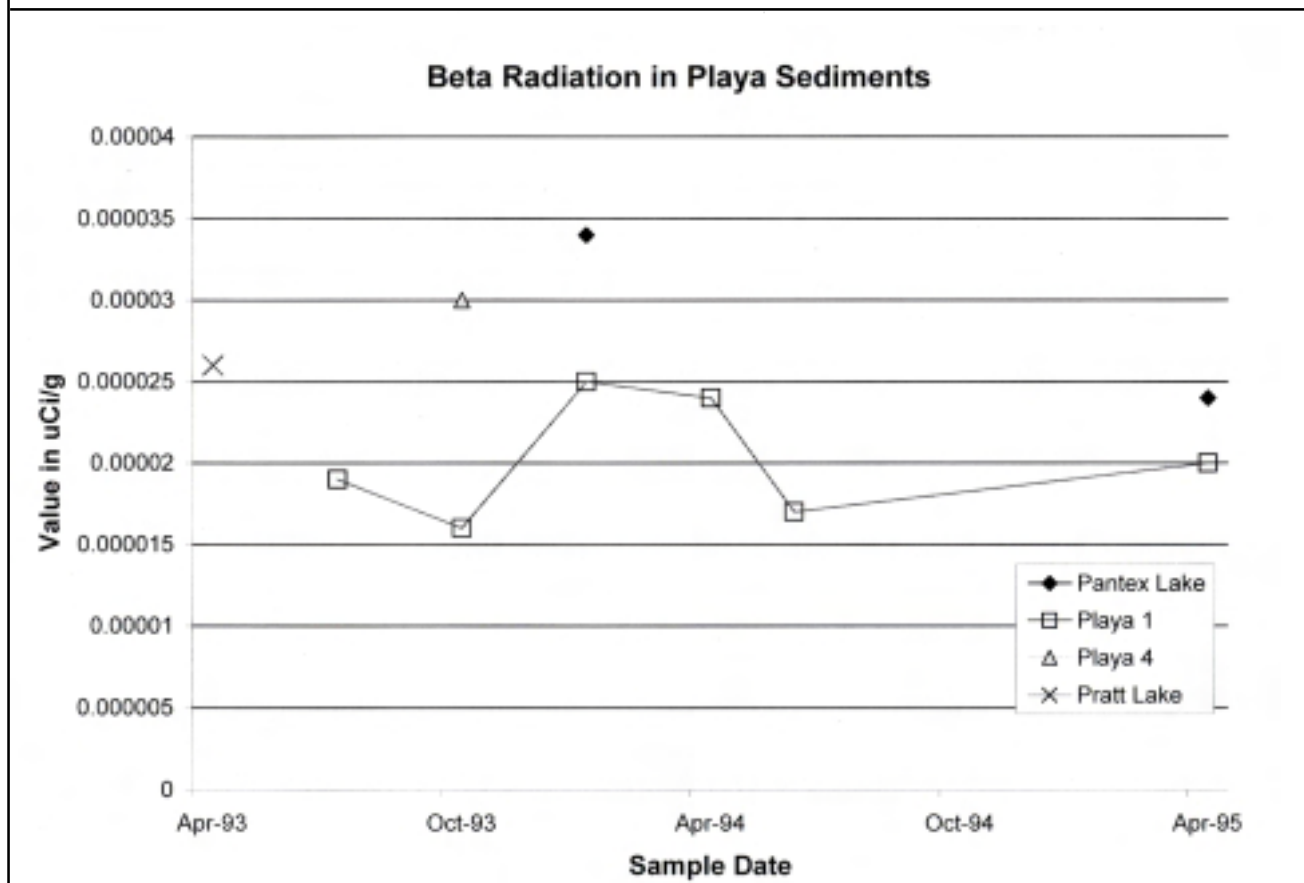
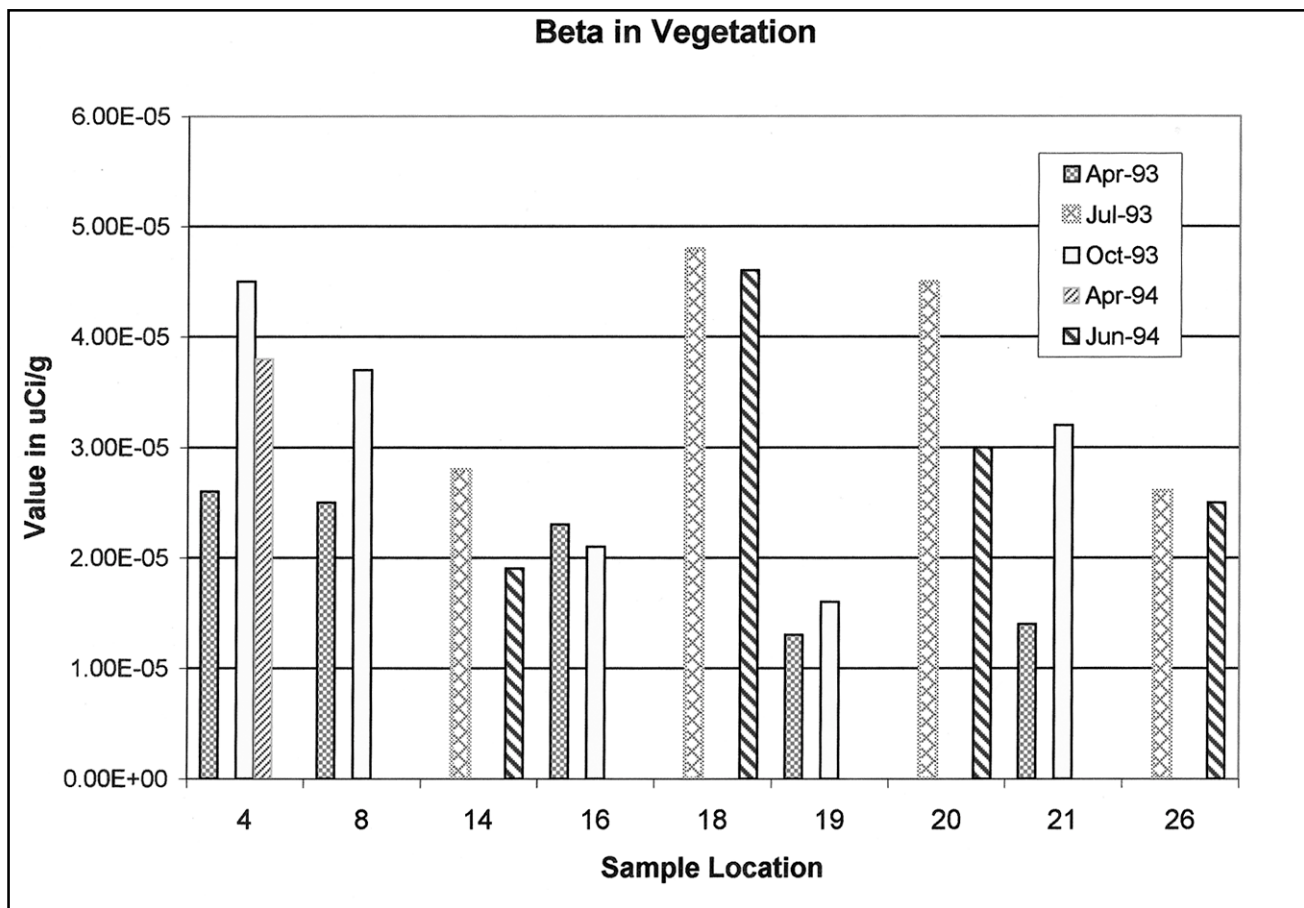


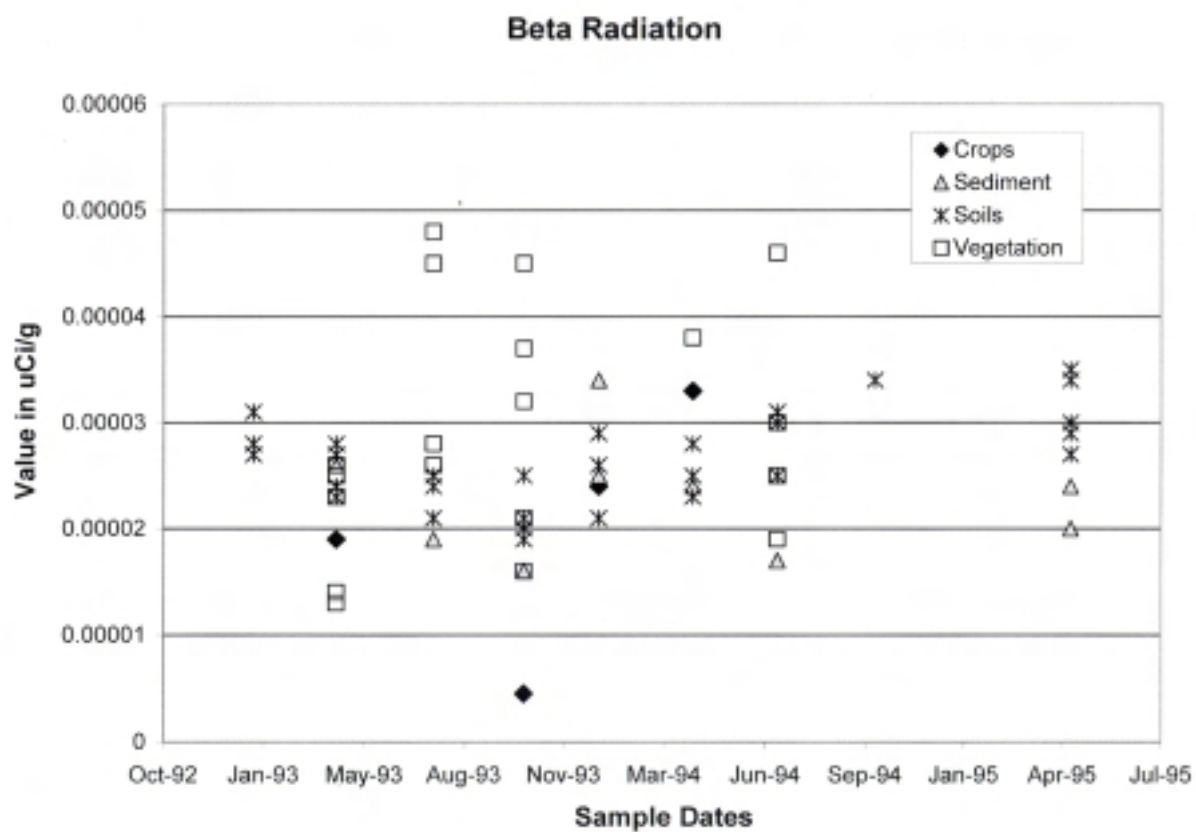
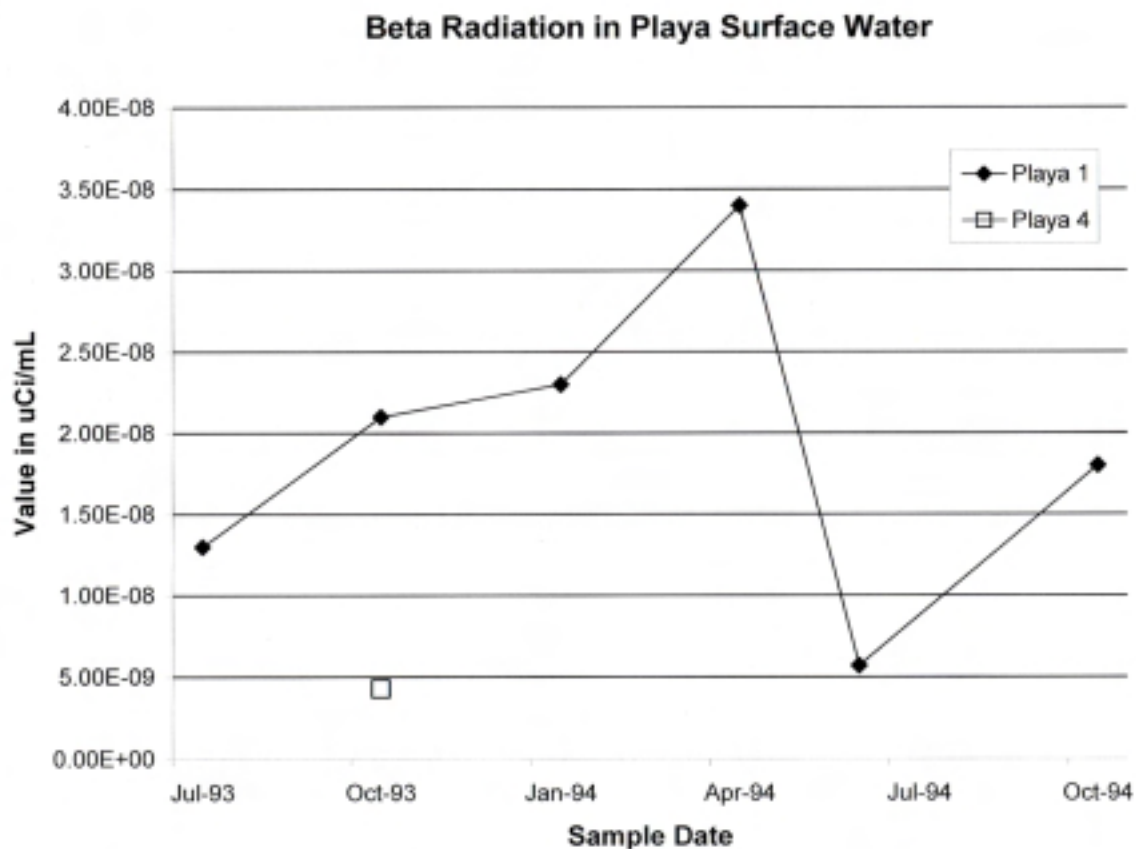
Radium-226 in Air, Station 104



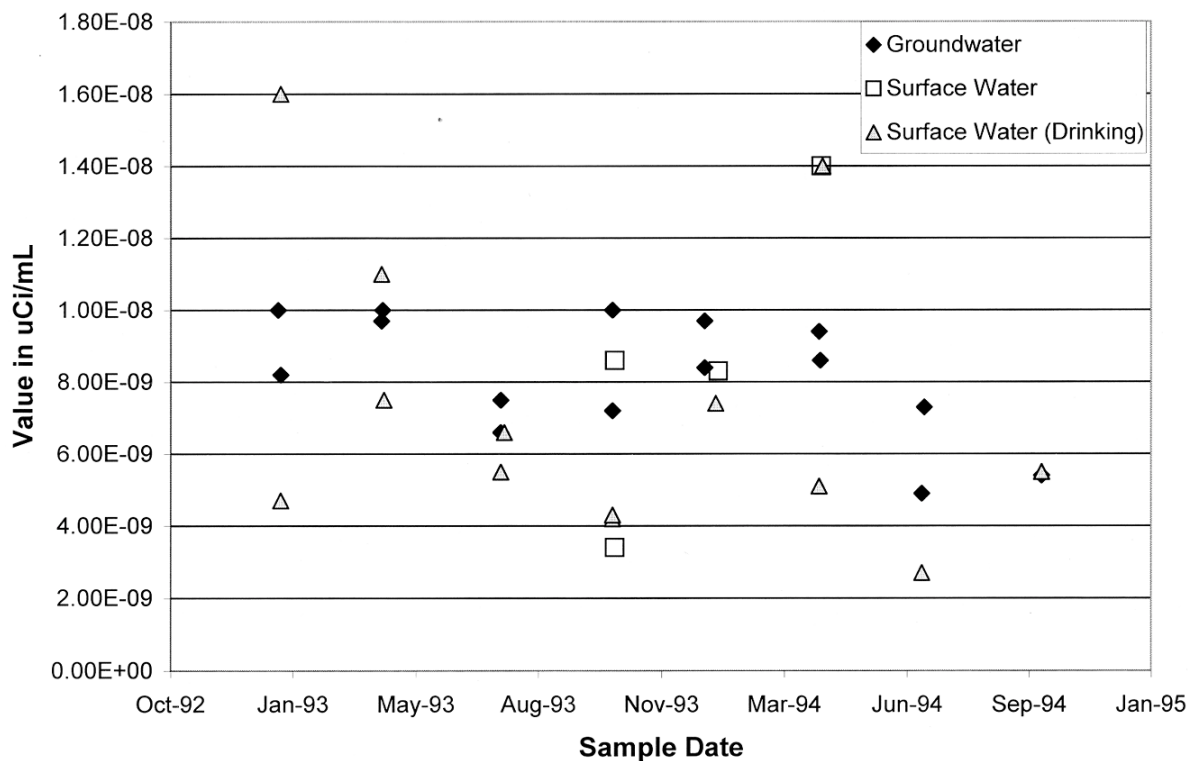
Radium 226 in Milk



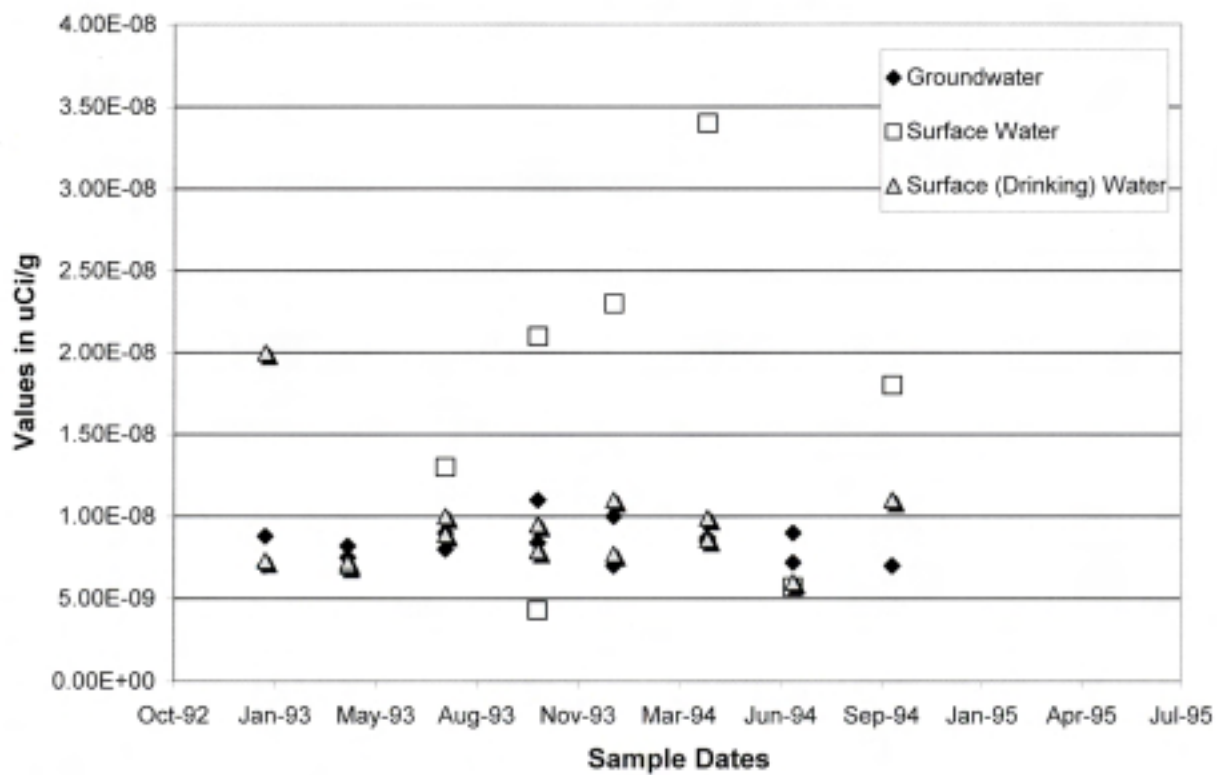




Alpha Radiation of Water



Beta Radiation of Water





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