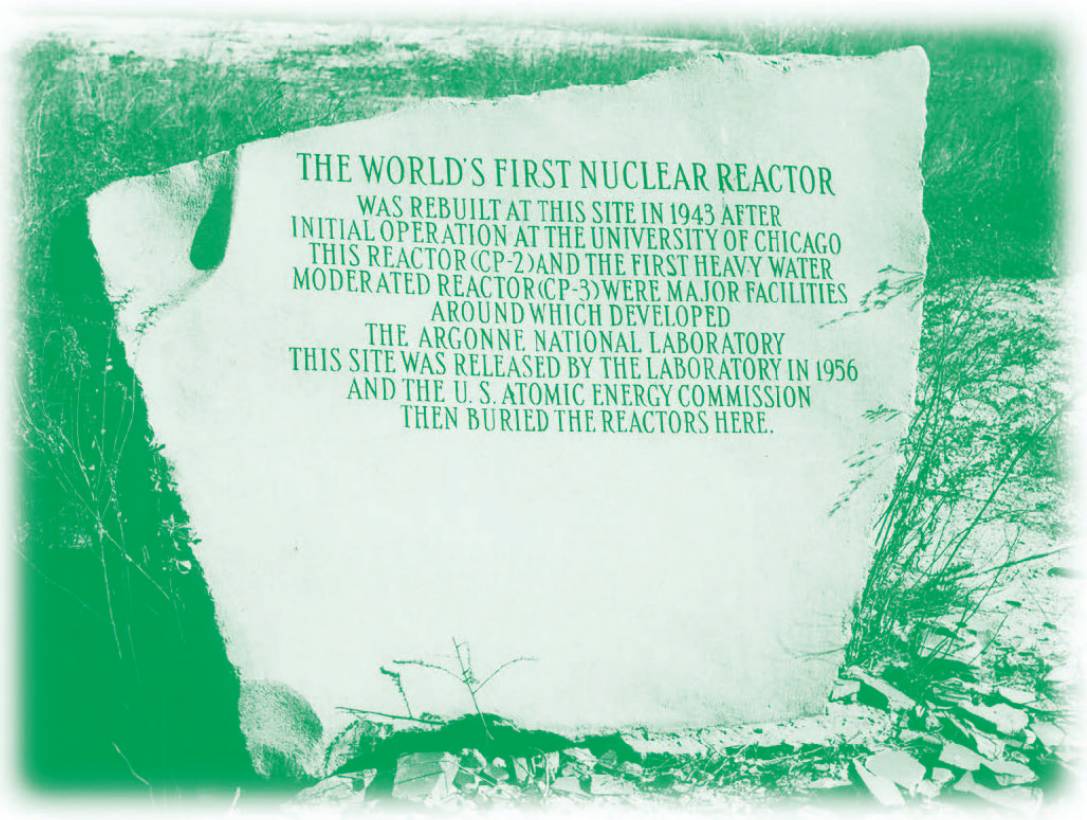
ANL-13/01

Surveillance of Site A and Plot M Report for 2012

Environment, Safety, and Quality Assurance



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ANL-13/01

Surveillance of Site A and Plot M Report for 2012

by

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Environment, Safety, and Quality Assurance Division, Argonne National Laboratory

May 2013

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PREFACE

This report is prepared for the U. S. Department of Energy (DOE) by the Environment, Safety, and Quality Assurance Division (ESQ) at Argonne National Laboratory (Argonne). The results of the environmental monitoring program at Site A and Plot M and an assessment of the impact of the site on the environment and the public are presented in this publication. Funding to support this program was provided by the DOE Office of Legacy Management (LM) through the DOE Grand Junction Office.

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SURVEILLANCE OF SITE A AND PLOT M

REPORT FOR 2012

ABSTRACT

The results of the environmental surveillance program conducted at Site A/Plot M in the Palos Forest Preserve area for Calendar Year 2012 are presented. Based on the results of a 1976-1978 radiological characterization of the site, a determination was made that a surveillance program be established. The characterization study determined that very low levels of hydrogen-3 (as tritiated water) had migrated from the burial ground and were present in two nearby hand-pumped picnic wells. The current surveillance program, which began in 1980, was modified in 2004 and currently consists of sample collection and analysis of surface and subsurface water. The results of the analyses are used to monitor the migration pathway of hydrogen-3 contaminated water from the burial ground (Plot M) to the hand-pumped picnic wells and monitor for the presence of radioactive materials in the environment of the area. Hydrogen-3 in the Red Gate Woods picnic wells was detected again this year. The hydrogen-3 in well 5160, in Red Gate Woods, was somewhat higher than in previous years. The hydrogen-3 concentrations in well 5159, across from Red Gate Woods, returned to historical averages after exhibiting higher than normal values in 2011. Hydrogen-3 continued to be detected in a number of other wells, boreholes, dolomite holes, and a surface stream. The very dry conditions that prevailed throughout much of 2012 may have caused unusually low groundwater elevations and higher than normal analytical results in several of the monitoring wells. Analyses since 1984 have indicated the presence of low levels of strontium-90 in water from a number of boreholes next to Plot M which continued in 2012. The results of the surveillance program continue to indicate that the radioactivity remaining at Site A/Plot M does not endanger the health or safety of the public visiting the site, using the picnic area, or living in the vicinity.

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1.0 INTRODUCTION

1.1 Site History

This report presents and discusses the surveillance data obtained during 2012. The surveillance program is the ongoing activity that resulted from the 1976-1978 radiological characterization of the former site of Argonne National Laboratory and its predecessor, the University of Chicago's Metallurgical Laboratory. This site was part of the World War II Manhattan Engineer District Project and was located in the Palos Forest Preserve southwest of Chicago, IL. The Laboratory used two locations in the Palos Forest Preserve: Site A, a 19-acre area that contained experimental laboratories and nuclear reactor facilities; and Plot M, a 150 ft x 140 ft area used for the burial of radioactive waste. The location of the Palos Forest Preserve is shown in Figure 1.1 and the locations of Site A and Plot M are shown in Figure 1.2. Previous comprehensive reports on this subject[1,2] provide additional detail and illustrations on sampling locations and provide descriptive material along with the results through 1981. There are annual reports available for 1982 through 2011.[3-32] While earlier data will not be repeated in this report, reference is made to some of the results.

Operations at Site A began in 1943 and ceased in 1954. Among the research programs carried out at Site A were reactor physics studies, fission product separations, hydrogen-3 recovery from irradiated lithium, and work related to the metabolism of radionuclides in laboratory animals. Radioactive waste and radioactively-contaminated laboratory articles from these studies were buried at Plot M. At the termination of the programs, the reactor fuel and heavy water, used for neutron moderation and reactor cooling, were removed and shipped to Oak Ridge National Laboratory. The biological shield for the CP-3 reactor located at Site A, together with various pipes, valves, and building debris, was buried in place in 1956.

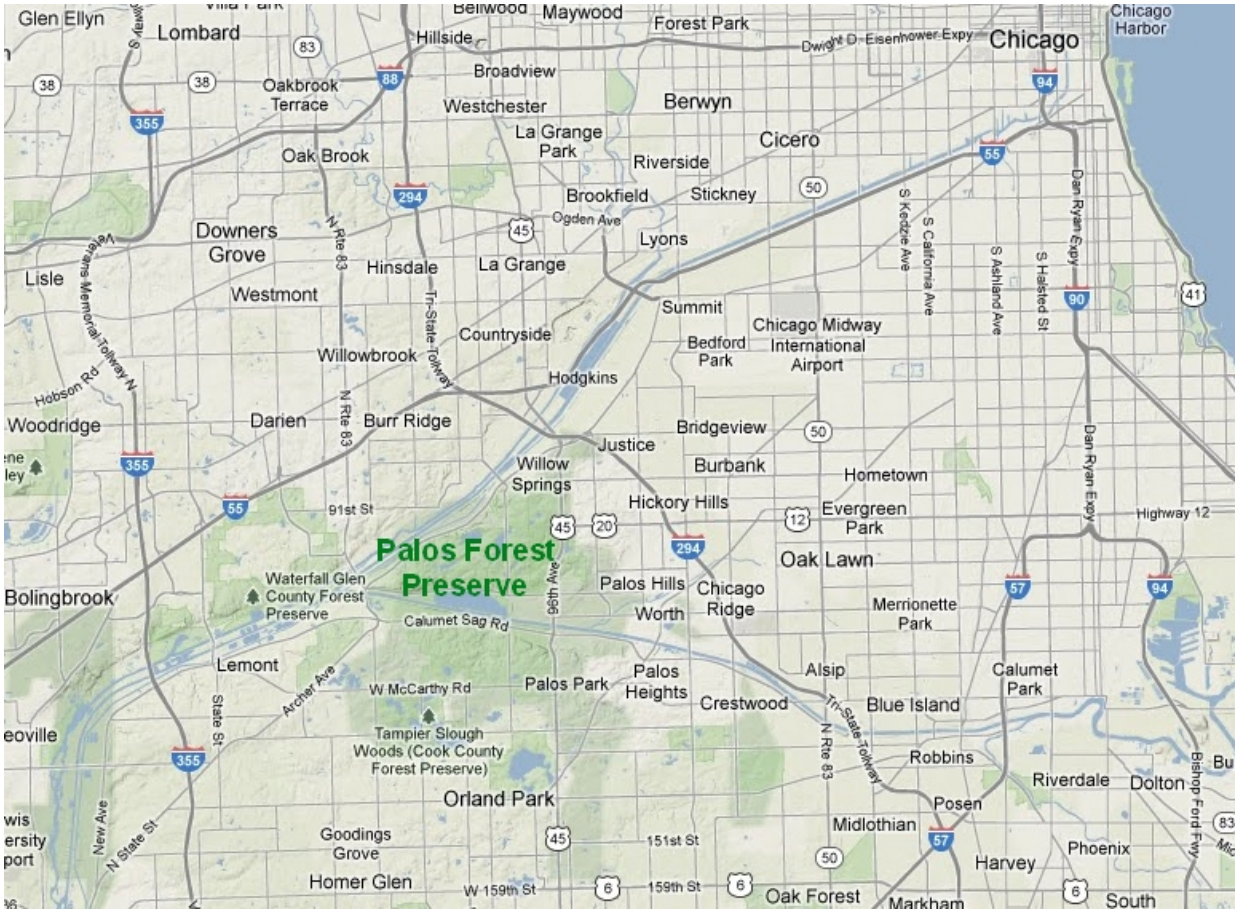

Figure 1.1 Location of Palos Forest Preserve on Chicago-Area Map

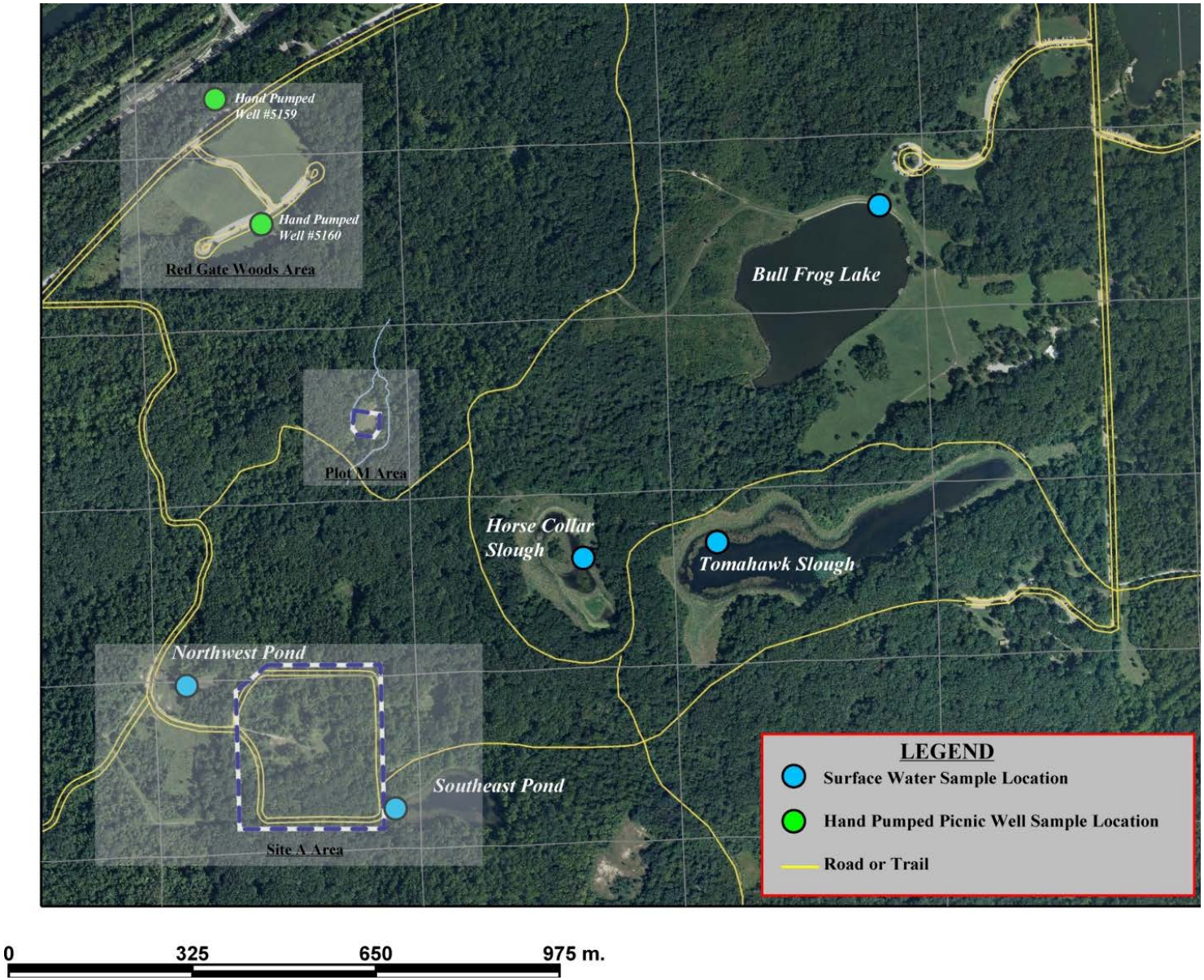

Figure 1.2 Palos Forest Preserve Showing Location of Site A/Plot M Surface Water Bodies and Former Picnic Wells

Burial of radioactive waste at Plot M began in 1944 and was discontinued in 1949. Waste was buried in six-foot deep trenches and covered with soil until 1948, after which burial took place in steel bins. The steel bins were removed in 1949 and sent to Oak Ridge National Laboratory for disposal, but the waste buried in trenches was allowed to remain in place. Concrete sidewalls, eight feet deep, were poured around the perimeter of the burial area and a one-foot thick reinforced concrete slab was poured over the top. The concrete slab was covered with soil and seeded with grass. Both the Site A and Plot M areas were decommissioned in 1956.

In 1973, elevated levels of hydrogen-3 (as tritiated water) were detected by Argonne in two nearby hand-pumped picnic wells (#5167 and #5159). Later investigations found the hydrogen-3 to be migrating from the Plot M burial plot into the surrounding soil and aquifers. As a result, a radiological survey of the entire Palos Forest Preserve site was conducted by Argonne in 1976 with special emphasis on the Site A and Plot M areas.[1]

In 1990, elevated levels of radioactivity were discovered outside the original developed area. By 1997, additional characterization and remediation had been completed by DOE to remove residual radioactivity and document the remediation of the area.

The terminology used in previous reports is continued in this report. A hole drilled and completed into the glacial drift is called a borehole. Some boreholes were cased and screened to form monitoring wells. Water from such wells is called groundwater. Monitoring wells drilled into the dolomite bedrock are called dolomite holes or deep holes. The hand-pumped drinking water wells, which are completed into or close to the dolomite bedrock, are called water wells or picnic wells. They are identified by a location name and well number.

The results of radioactivity measurements are expressed in this report in terms of picocuries per liter (pCi/L) for strontium-90 and nanocuries per liter (nCi/L) for hydrogen-3 in water samples. Radiation effective dose equivalent calculations are reported in units of millirem (mrem) or millirem per year (mrem/y). The use of the term dose throughout this report means effective dose equivalent. Other abbreviations of units are defined in the text.

1.2 Site Characteristics

Geologically, Plot M is constructed on a moraine upland which is dissected by two valleys, the Des Plaines River valley to the north and the Calumet Sag valley to the south. The upland is characterized by rolling terrain with poorly developed drainage. Streams are intermittent and drain internally or flow to one of the valleys. The area is underlain by glacial drift, dolomite, and other sedimentary rocks. The uppermost bedrock is Silurian dolomite, into which both the picnic wells and some of the monitoring wells are placed, as described in the text. The dolomite bedrock is about 200 feet thick. The overlying glacial drift has a thickness that ranges from 165 feet at Site A to zero at the Des Plaines River and Calumet Sag Canal, and some of the monitoring wells terminate in this layer. The depth to bedrock at Plot M is about 130 feet.

Hydrologically, the surface water consists of ponds and intermittent streams. When there is sufficient precipitation, the intermittent stream that drains Plot M flows from the highest point near Site A, past Plot M, then continues near the Red Gate Woods well (#5160 in Figure 1.2) and discharges into the Illinois and Michigan (I&M) Canal. The groundwater in the glacial drift and dolomite forms two distinct flow systems. The flow in the drift is controlled principally by topography. The flow in the dolomite, which is recharged by groundwater from the glacial drift, is controlled by two discharge areas, the Des Plaines River to the north and the Calumet Sag Canal to the south. There is no groundwater usage downgradient of Site A/Plot M. The two remaining former hand-pumped picnic wells have been disabled by removing the handles. These wells are currently used only for groundwater monitoring.

The climate is that of the upper Mississippi valley, as moderated by Lake Michigan, and is characterized by cold winters and hot summers. Precipitation averages about 37 inches annually. The largest rainfalls occur between April and September. The average monthly temperature ranges from 21°F in January to 73°F in July. Approximately 8.9 million people reside within 50 miles of the site; the population within a five-mile radius is about 150,000. The only portion of the Palos Forest Preserve in the immediate area of Plot M and Site A that is developed for public use is the Red Gate Woods picnic area (Figure l.2), although small numbers of individuals use the more remote areas of the Palos Forest Preserve.

The weather during most of 2012 was unusually hot and dry with many record high temperatures and low precipitation amounts. The total precipitation amount for the year was approximately 21 cm (8.3 inches) below normal. As a result of these dry conditions, groundwater surface elevations were lower than normal and a number of wells were dry during the last two quarters. There was no surface water flow during the third or fourth quarters of 2012 and the seep at location No. 6 dried up completely.

1.3 Purpose of Monitoring Program

The monitoring conducted at Site A/Plot M was conducted in accordance with the Long-Term Surveillance and Maintenance Plan for Site A and Plot M, Palos Forest Preserve, Cook County, Illinois, issued in December 2004[33]. DOE−LM conducts stewardship activities at Site A and Plot M to protect human health and the environment and to comply with applicable regulations. The overall goal of this plan is to maintain protectiveness at the site through a combination of government ownership, conducting regular inspections, maintaining public awareness, and monitoring environmental media and institutional controls. This report discusses the results of the monitoring portion of this plan.

The sampling locations for the monitoring program are based on technical and stakeholder concerns. The distribution of sampling locations was chosen to ensure that conditions will be known to remain protective. The main constituents of concern (COC) in groundwater and surface water at Site A/Plot M are hydrogen-3 and strontium-90. The current

monitoring program is focused on these parameters. The Long Term Stewardship Plan defines the following two major monitoring objectives:

- Ensure that existing contaminant concentrations continue to decrease as expected due to radioactive decay and other natural processes, and

- Detect any potential future releases.

The monitoring program is assessed every three to five years to determine if these goals are being met. At each review, changes to the monitoring program may be recommended. Since several of the wells and surface water locations currently exceed the Illinois EPA Class I Ground Water Quality Standards for hydrogen-3, it is likely that monitoring of Site A/Plot M will continue for the foreseeable future, with occasional modifications to the sampling program. Once the hydrogen-3 concentrations at all sampling locations have decreased to less than the groundwater quality standards, it is possible that monitoring will be terminated.

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2.0 SUMMARY

Surface water samples were collected each quarter when water was present during 2012 from two streams that flow around Plot M. They showed the same hydrogen-3 concentration pattern seen in the past. Concentrations were at the ambient level of less than 0.1 nCi/L upstream of the Plot, increased up to 118 nCi/L at the seep adjacent to the Plot, decreasing to a maximum of 63 nCi/L downstream. The hydrogen-3 concentrations in the seep during 2012 were the highest results observed since 1999, although a similarly elevated value was seen in 2005, another year with drought conditions. There was no flow from the seep during the third or fourth quarter of 2012.

Samples of surface water from five ponds near Site A, shown in Figure 1.2, were collected and analyzed for hydrogen-3. None of the ponds contained detectable amounts of hydrogen-3. One pond was dry during the third quarter and no sample could be collected.

The hydrogen-3 concentrations in the samples from the boreholes and dolomite holes follow a pattern generally consistent with that observed in the past. The hydrogen-3 concentration was highest in those boreholes nearest Plot M and downgradient of the Plot. Water from four of nine boreholes analyzed for strontium-90 contained concentrations greater than the detection limit of 0.25 pCi/L. The highest strontium-90 levels (up to 2.96 pCi/L) were found in the slant borehole installed directly below the waste and is probably due to migration of strontium-90 before Plot M was capped. Strontium-90 is a relatively mobile radionuclide and its presence in the borehole water is not unexpected. The strontium-90 results are consistent with those measured in the past.

Samples of water from the two disabled picnic wells shown in Figure 1.2 were collected each quarter of 2012. The maximum and average hydrogen-3 concentrations of well #5160 in 2012 were 2.1 nCi/L and 1.6 nCi/L, respectively, the highest since 1997. The well opposite the entrance to Red Gate Woods (#5159) had a maximum hydrogen-3 concentration of 0.74 nCi/L and an annual average concentration of 0.34 nCi/L. These results were similar to results found previous to 2011. The 2011 results were anomalously high in this well.

Since there is no consumption of water from these wells, the hydrogen-3 present does not represent a health risk. However, estimating the potential exposure if this water were consumed provides a basis to compare the significance of these findings. If water equal to the Red Gate Woods North Well (#5160) with an average hydrogen-3 concentration of 1.6 nCi/L was the sole source of water for an individual, the annual dose from hydrogen-3 would be 0.085 mrem using the DOE derived concentration technical standard.[34] Consumption of one liter of this water would produce a dose of 0.00012 mrem. Similarly, if the well opposite Red Gate Woods (#5159) with an average hydrogen-3 concentration of 0.34 nCi/L was assumed to be the sole source of water, the annual dose would be 0.018 mrem. The dose for a single liter of this water would be 0.000024 mrem. Although the U. S. Environmental Protection Agency (EPA) drinking water regulations[35] are not applicable because the former picnic wells would not meet the EPA definition of a public drinking water supply if they were still operational, these concentrations are only 2-8% of the EPA Primary Drinking Water standard of 20 nCi/L. The Illinois Class I Groundwater Quality Standards utilize this limit for groundwater in Illinois as stipulated by 35 IAC 620.410. Table 4.3 provides a relative comparison of this calculated dose to natural and other sources of radiation.

The results of this program show that the radioactivity remaining at Site A, Plot M, and the Red Gate Woods area does not endanger the health or safety of the public visiting the site or those living in the vicinity. The potential radiation doses are very low compared to the relevant standards.

3.0 MONITORING PROGRAM

The Site A/Plot M program follows the guidance for monitoring at DOE facilities.[36] Although it is recognized that Site A/Plot M is not a DOE facility, the same monitoring principles are applicable to this site. The monitoring program is designed to assess the current status of past releases of hydrogen-3 and strontium-90 from the site and to monitor elevated hydrogen-3 (as tritiated water) concentrations previously detected in some of the former picnic wells in the Palos Forest Preserve. This is accomplished by analyzing water from wells, deep holes, and surface water in the area. Samples are collected with a frequency ranging from quarterly to semiannually, depending on past results and proximity to Plot M.

In early 2004, a review of the monitoring program was conducted to determine the optimum monitoring strategy for Site A/Plot M. The evaluation of over 20 years of monitoring data revealed a significant reduction of hydrogen-3 and strontium-90 concentrations in surface water and groundwater. DOE-LM staff worked closely with the property owner, representatives from the State of Illinois, Argonne National Laboratory, local stakeholders, and the DOE Chicago Operations Office to develop an environmental monitoring program that focuses on pathways and locations that provide the most pertinent information. A number of sampling locations were deleted, sampling frequencies were changed, and the analyses reduced to target hydrogen-3 and strontium-90 only. The streamlined program was implemented in early 2004 and this program was followed in 2012.

During 2012, 139 samples were collected, 169 analyses were performed, and 96 field measurements were conducted. Individual results are presented in this section. Where applicable, results are compared to the U. S. Department of Energy Radiation Protection Standard of 100 mrem/y.[37]

The uncertainties associated with individual concentrations given in some of the tables are the statistical counting errors at the 95% confidence level. Because of the amount of hydrogen-3 data presented in many of the tables, the uncertainty values are not included. In such cases, the following typical uncertainties apply:

Hydrogen-3 Concentration (nCi/L)	Uncertainty (% of Conc.)
0.1-1.0	40-5%
1-10	5-1%
> 10	1%

The detection limit for hydrogen-3 in water is 0.1 nCi/L and 0.25 pCi/L for strontium-90 in water.

3.1 Surface Water

Water samples were collected at four sampling locations during the first two quarters of 2012 from the two streams that flow around Plot M. The sampling locations are shown in Figure 3.1. There was no flow present during the third and fourth quarter of 2012, thus no samples were collected. The two sets of samples were analyzed for hydrogen-3 and the results are shown in Table 3.1. The same concentration pattern in the water flowing around Plot M was observed this year as in the past. Concentrations were below the detection limit upstream of Plot M (Location 1); hydrogen-3 was found in the seep water that leached out of the burial site (Location 6); and lower concentrations were found downstream of the Plot (Locations 7 & 8). The amounts of hydrogen-3 found in 2012 were higher than in the previous few years, though results similar to those found were measured in 2005 and 2008. Hydrogen-3 concentrations have been found to vary from year to year, depending in part on the amount of precipitation prior to sample collection. Despite seasonal variations, in general the hydrogen-3 concentrations in the seep have exhibited a steady decline since the 1990s.

Samples were collected quarterly from five surface water bodies in the vicinity of Site A. They are the pond northwest of Site A; the pond southeast of Site A; Horse Collar Slough; Tomahawk Slough; and Bull Frog Lake. These locations are identified in Figure 1.2. During the third quarter of 2012 the water level in Horse Collar Slough was so low a water sample could not be collected. The samples were analyzed for hydrogen-3 and the results are presented in Table 3.2. All hydrogen-3 concentrations were below the detection limit of 0.1 nCi/L.

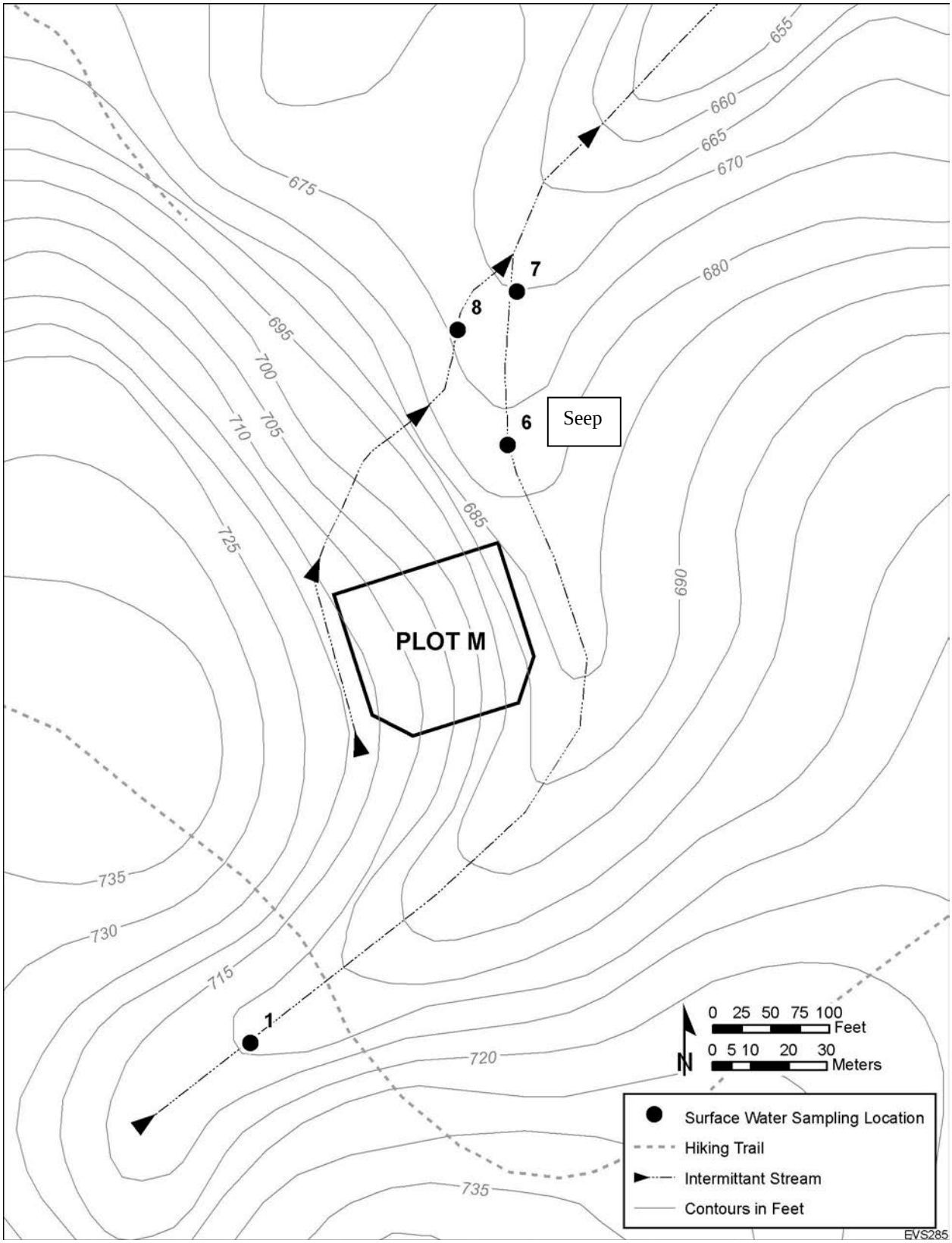

Figure 3.1 Stream Sampling Locations near Plot M

Table 3.1

Hydrogen-3 Content of Stream Next to Plot M, 2012
(Concentrations in nCi/L)

Location Number[1]	Date Collected			
	January 6	May 3	3rd Quarter	4th Quarter
1	< 0.1	< 0.1	DRY	DRY
6 (Seep)	118	103	DRY	DRY
7	45	63	DRY	DRY
8	11	11	DRY	DRY

[1] See Figure 3.1

Table 3.2

Hydrogen-3 Content of Site A Area Ponds, 2012
(Concentrations in nCi/L)

Location[1]	Date Collected			
	January 6	May 21	August 3	October 11
NW Site A	< 0.1	< 0.1	< 0.1	< 0.1
SE Site A	< 0.1	< 0.1	< 0.1	< 0.1
Bull Frog Lake	< 0.1	< 0.1	< 0.1	< 0.1
Horsecollar Slough	< 0.1	< 0.1	DRY	< 0.1
Tomahawk Slough	< 0.1	< 0.1	< 0.1	< 0.1

[1] See Figure 1.2

3.2 Subsurface Water

3.2.1 Monitoring Wells - Plot M

A number of boreholes are present in and around the Plot M area (Figure 3.2) that are fitted with plastic casing and screens to serve as monitoring wells within the glacial drift. Two wells (BH09 and BH10) are drilled at a 45° angle under the waste. Water samples were collected and water level measurements were made in these nine Plot M monitoring wells quarterly. The two slant wells, BH09 and BH10, were both dry during the third and fourth quarter. Well BH11 contained only enough water during the fourth quarter for the hydrogen-3 sample; therefore, the strontium-90 sample was not collected that quarter.

All the water samples were analyzed for hydrogen-3 and the results are shown in Table 3.3; duplicate quality control sample results are shown in parentheses. The hydrogen-3 concentrations varied widely from well to well. With the exception of several wells, the magnitudes of the hydrogen-3 concentrations are similar to those observed over the past several years.

During the fourth quarter, well BH02 had a hydrogen-3 concentration of 833 nCi/L (a duplicate sample had a result of 793 nCi/L). This result was the highest since 2005 and much higher than the last few years. Samples collected during 2000, 2002 and 2005 contained similarly high levels of hydrogen-3. Figure 3.3 shows hydrogen-3 concentrations in this well since 1990. It also contains a chart of groundwater elevations. The high values found in 2003, 2005 and 2012 are associated with very dry conditions during those years as evidenced by the low groundwater elevations that were measured at the time the sample were collected. However, a spike in hydrogen-3 concentration recorded in 2001 is not as closely associated with low groundwater levels.

Well BH35 hydrogen-3 concentrations, shown in Figure 3.4, appear to be increasing over the last few years; however, the concentrations measured in 2012 were similar to concentrations recorded prior to 2000.

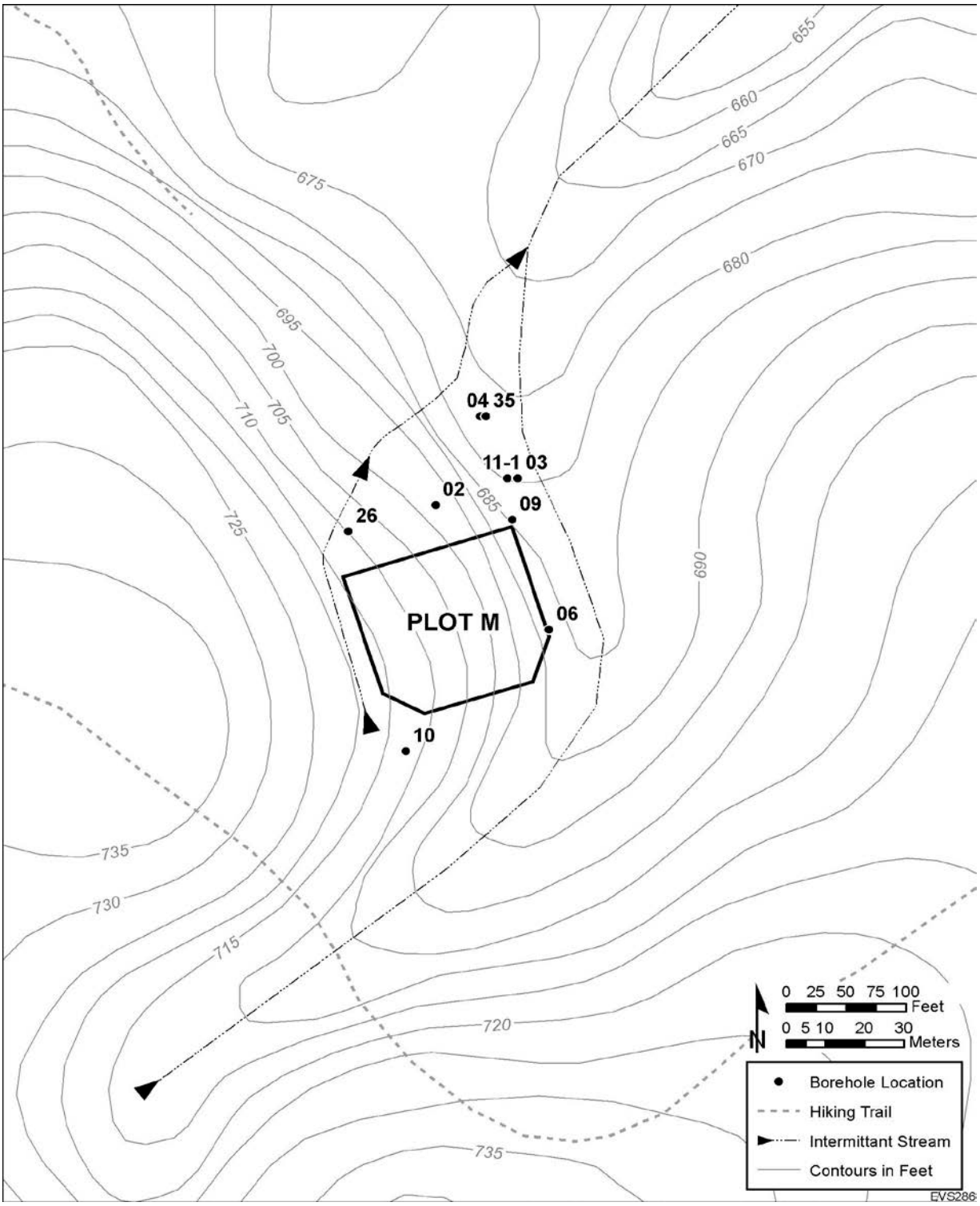

Figure 3.2 Map of Plot M Palos Site Showing Topography, Intermittent Stream, and Monitoring Well Locations

Table 3.3

Hydrogen-3 Content of Plot M Monitoring Well Water, 2012
(Concentrations in nCi/L)

Borehole Number	Depth (ft)	Date Collected			
		5-Mar	21-May	12-Sep	20-Nov
02	39.41	9.1	14	44	822 (793)[1]
03	40.00	288	335	319	339
04	36.05	390	384	372	369
06	40.30	169	190	488	464
09	40.00[2]	937	740	DRY	DRY
10	40.00[2]	38 (38)	38	DRY	DRY
11	39.30	115	125 (124)	117	114
26	60.65	200	193	194 (197)	190 (188)
35	105.50	509	521	570	571

[1] Duplicate QC sample results are denoted by parentheses.

[2] Slant hole drilled at 45º to a depth of 40 ft below the surface.

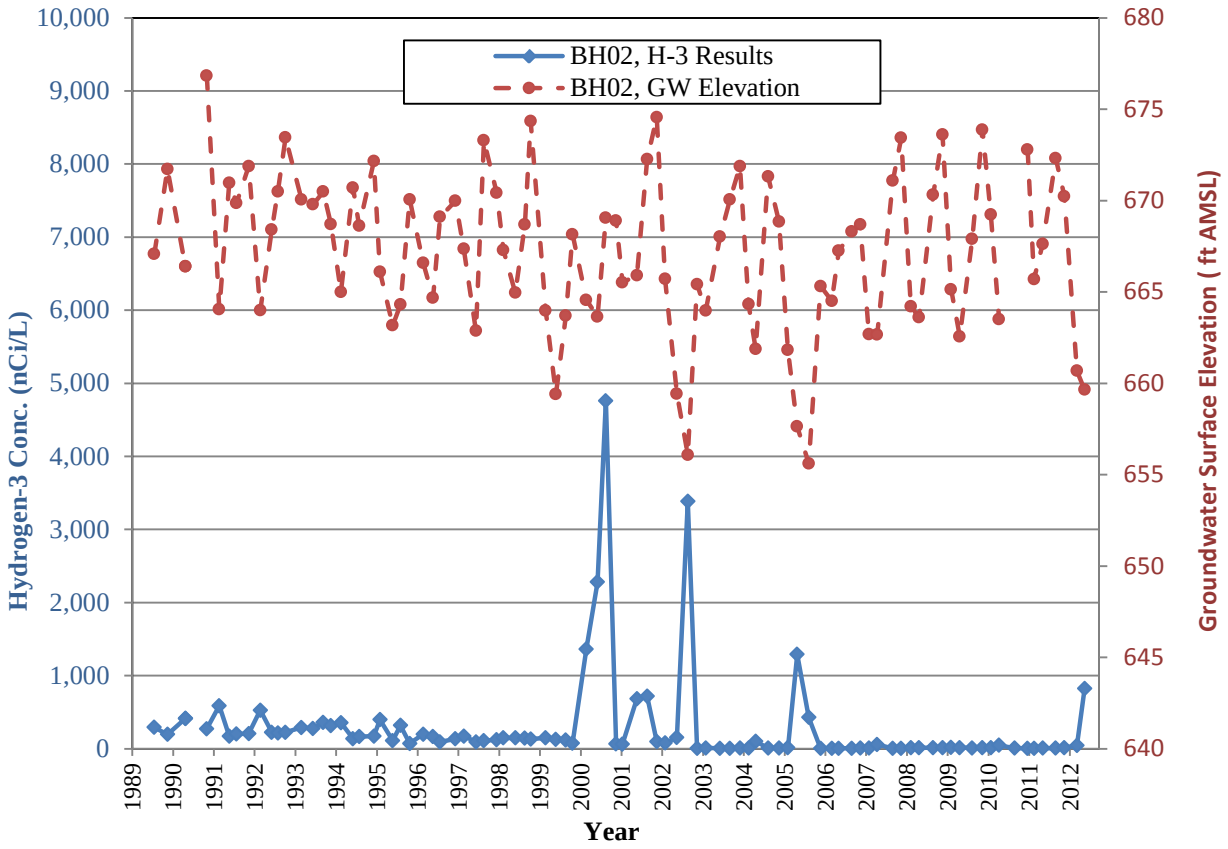

Figure 3.3 Hydrogen-3 and Groundwater Elevation in Well BH02

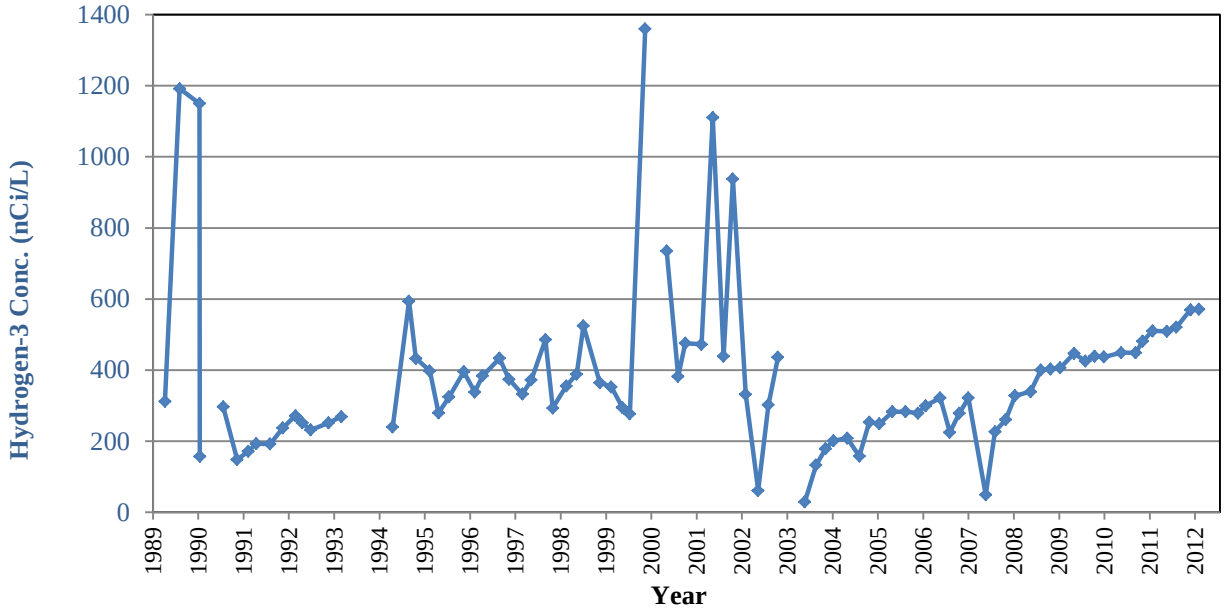

Figure 3.4 Hydrogen-3 in Well BH35

Since 2008, well BH06 has exhibited an increasing trend in hydrogen-3 concentrations, as seen in Figure 3.5, which also shows groundwater elevations in this well. That trend continued in 2012, though the highest concentration was lower than the peak concentration of 1534 nCi/L found in 2011. Between 1993 and 1995 groundwater elevation decreased by approximately 20 feet, for unknown reasons, and has remained relatively low. From 1995 through 2007, hydrogen-3 levels exhibited a slow, steady decline, which has changed to the increasing trend seen during the last four years. During this same period, groundwater elevation in this well also increased slightly, to a point in early 2012 where it was higher than at any time since 1994. The 2012 drought cause a rapid decrease in groundwater elevation during the last two quarters. The changing groundwater elevations could be responsible for the recent increase in hydrogen-3 concentrations.

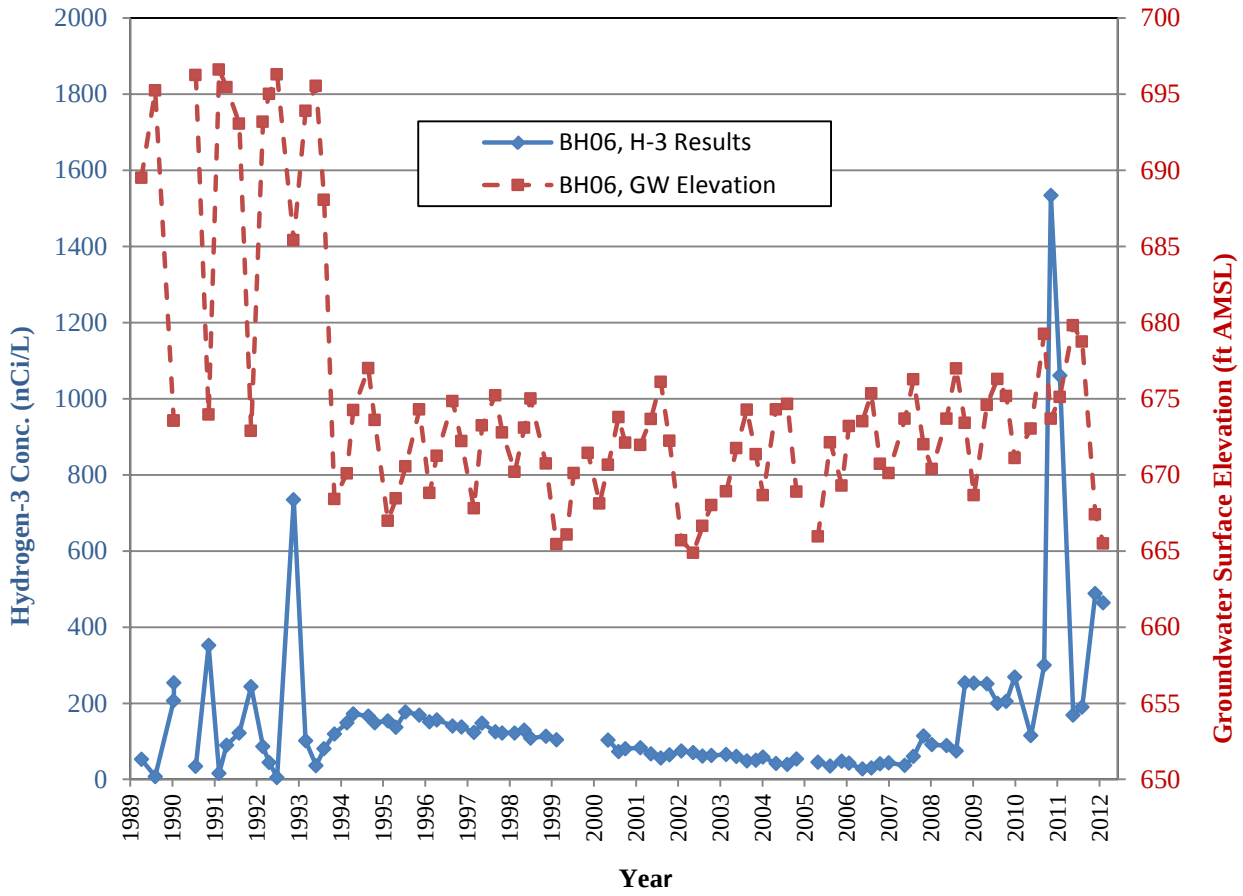

Figure 3.5 Hydrogen-3 and Groundwater Elevation in Well BH06

Boreholes BH03 and BH04, which historically contained some of the highest hydrogen-3 concentrations, continued to show a steady decline during 2012. BH09, which is a slant well screened directly beneath the waste trenches, has often contained high and highly variable hydrogen-3 concentrations. The concentrations from the two samples collected in 2012 were similar to the years prior to 2011, which had unusually low levels of hydrogen-3.

Groundwater elevations in most of the shallow wells were found to decrease throughout 2012 due to the dry conditions throughout the year. By the end of the year, groundwater elevations had dropped to levels not seen since the drought in 2005. The water levels in BH35, the single deeper drift well, which is 105 ft. deep, were relatively constant throughout the year. The depth to groundwater and groundwater elevations in the vertical wells are shown in Table 3.4. Groundwater elevations for the two slant wells are not included in this table since the angle of the well distorts the depth to water values.

Groundwater from the monitoring wells was analyzed twice for strontium-90. Large volume water samples were collected to obtain greater sensitivity in the analysis. One set of samples was collected on May 21, 2012, and another set was collected November 20, 2012. Samples were collected from all wells that yielded sufficient water for analysis. Well BH11 did not yield sufficient water for the strontium-90 sample during the fourth quarter of 2012, thus no sample was collected. The results are shown in Table 3.5. Strontium-90 concentrations greater than the detection limit of 0.25 pCi/L were found in four of the nine sampled wells. Levels above 0.25 pCi/L would not be expected in this water due to past radioactive fallout, and no other source is known, thus the source is likely to be waste in Plot M. The highest strontium-90 concentration in 2012 was 2.96 pCi/L in water from BH09. All results are less than the State of Illinois Class 1 Ground Water Quality Standard value of 8 pCi/L. As in the past, BH06, which is between the buried waste and the stream that flows around Plot M, showed measurable strontium-90 concentrations. The data suggest that small but measurable amounts of strontium-90 have migrated from the waste into the surrounding glacial drift.

Table 3.4
Water Level Measurements in Monitoring Wells Near Plot M, 2012

			Date Measured							
			March 5		May 21		September 12		November 20	
Well Number[1]	Depth to Bottom (ft.)	Top of Casing Elevation (ft AMSL)[2]	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation
02	39.41	692.70	20.39	672.31	22.47	670.23	32.02	660.68	33.05	659.65
03	40.00	693.30	30.41	662.89	30.15	663.15	35.86	657.44	38.40	654.90
04	36.05	682.20	13.82	668.38	13.52	668.68	23.72	658.48	27.20	655.00
06	40.30	704.90	25.09	679.81	26.16	678.74	37.50	667.40	39.41	665.49
11	39.30	693.00	18.60	674.40	21.17	671.83	30.15	662.85	33.80	659.20
26	60.65	692.30	42.50	649.80	41.31	650.99	46.15	646.15	48.62	643.68
35	105.50	682.40	94.27	588.13	93.87	588.53	94.03	588.37	93.21	589.19

[1] Water depth for wells 09 and 10 are not shown since these are slant wells

[2] From 1994 IT study report

Table 3.5

Strontium-90 Content of Monitoring Well Water Samples Near Plot M, 2012
(Concentrations in pCi/L)

Well Number[1]	Depth (ft.)	May 21	November 20
02	39.41	0.29 ± 0.03	0.33 ± 0.04
03	40.00	< 0.25	< 0.25
04	36.05	< 0.25	< 0.25
06	40.30	1.18 ± 0.10	0.91± 0.08
09	40.00[2]	2.96 ± 0.24	DRY
10	40.00[2]	<0.25	DRY
11	39.30	2.03 ± 0.17 (2.08 ± 0.17)[3]	Insufficient water[4]
26	60.65	<0.25	<0.25 (<0.25)
35	105.50	<0.25	<0.25

[1] See Figure 3.2

[2] Wells 09 and 10 are slant wells

[3] Duplicate QC sample results are denoted by parentheses

[4] During the fourth quarter well 11 did not yield sufficient water for the Sr90 sample. Only the H3 sample was collected

Hydrogen-3 results for the Site A monitoring well samples are shown in Table 3.6. The results of duplicate QC samples are shown in parentheses. The hydrogen-3 concentrations were all low and consistent with previous results, with the highest result being in wells BH55 and BH56. The hydrogen-3 in BH55 and BH56 most likely is from the buried CP-3 biological shield. The hydrogen-3 concentrations at Site A were several orders of magnitude lower than Plot M. The results of the strontium-90 analyses are shown in Table 3.7. The elevated strontium-90 results appear to track with elevated hydrogen-3 results. BH55 and BH56 had measurable levels of hydrogen-3 and strontium-90 throughout the year.

Water levels were also measured in these monitoring wells and these measurements appear in Table 3.8. The same trend of decreasing groundwater elevation throughout the year that was seen at Plot M can be seen in this area as well.

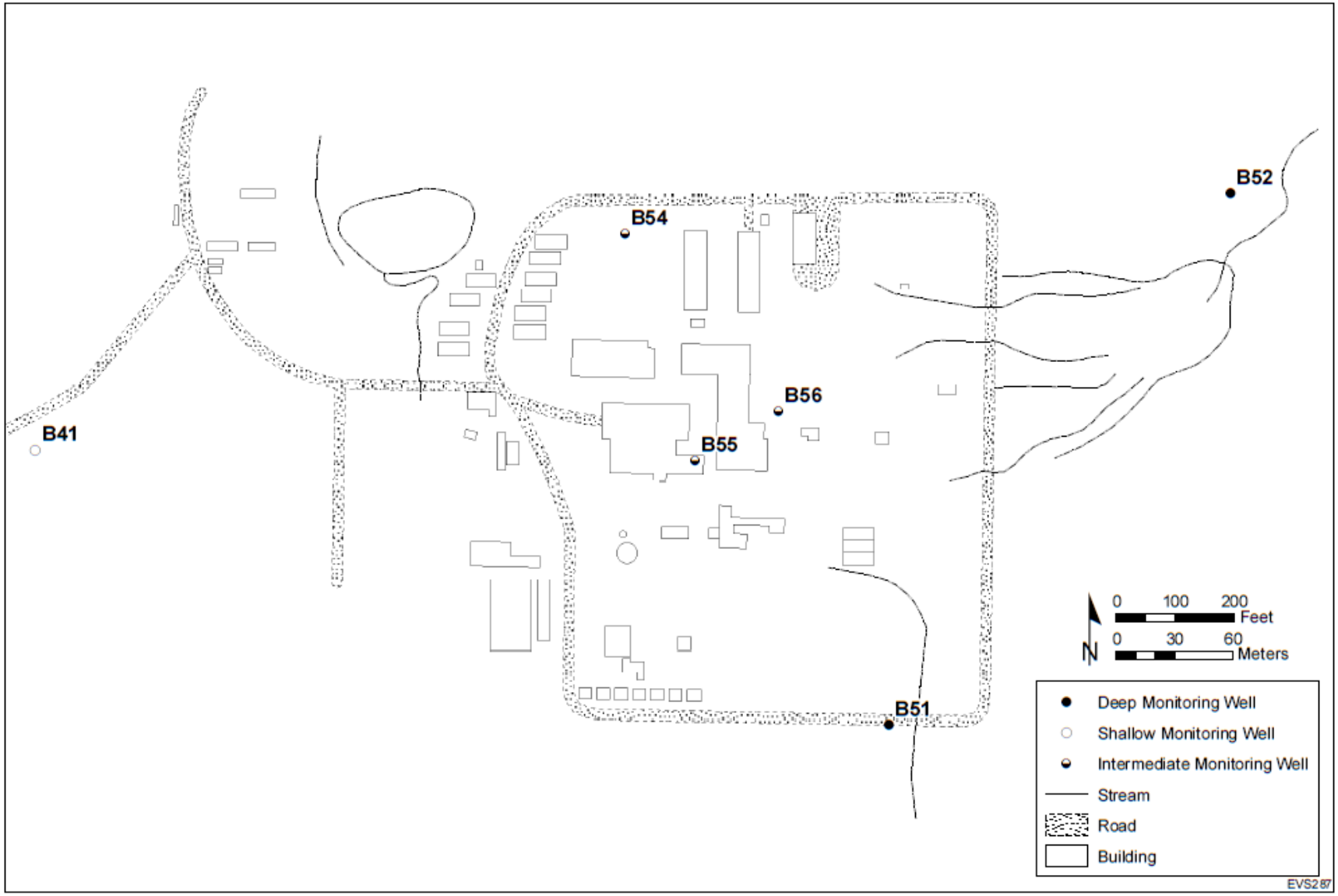

Figure 3.6 Monitoring Wells at Site A

Table 3.6

Hydrogen-3 Content of Site A Borehole Water, 2012
(Concentrations in nCi/L)

Well Number	Depth (ft.)	Date Collected			
		March 22	May 31	September 13	November 20
B41	25.83	<0.1	0.12	0.16 (0.16)	0.28
B51	116.40	< 0.1	< 0.1	< 0.1	< 0.1
B52	165.00	< 0.1	< 0.1	< 0.1	< 0.1
B54	63.40	0.11	<0.1	0.10	0.14 (<0.1)
B55	87.20	1.4 (1.4)	1.3	1.8	1.7
B56	102.40	2.2	1.7 (1.7)	1.8	2.2

Table 3.7

Strontium-90 Content of Monitoring Well Water Samples Near Site A, 2012
(Concentrations in pCi/L)

Borehole Number	Depth (ft.)	Date Collected	
		March 22	September 13
B41	25.83	< 0.25	< 0.25 (<0.25)
B51	116.40	< 0.25	< 0.25
B52	165.00	< 0.25	< 0.25
B54	63.40	< 0.25	< 0.25
B55	87.20	0.58±0.06 (0.63±0.06)	1.13±0.10
B56	102.40	1.26±0.11	1.30±0.11

Table 3.8
Water Level Measurements in Monitoring Wells Near Site A, 2012

			Date Measured							
			March 22		May 31		September 13		November 20	
Well Number[1]	Depth to Bottom (ft.)	Top of Casing Elevation (ft AMSL)[1]	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation
B41	25.83	737.38	1.81	735.57	5.28	732.10	14.07	723.31	17.42	719.96
B51	116.40	715.93	100.78	615.15	100.76	615.17	100.88	615.05	100.59	615.34
B52	165.00	713.43	131.60	581.83	131.75	581.68	132.66	580.77	132.88	580.55
B54	63.40	732.03	54.53	677.50	53.32	678.71	56.34	675.69	57.05	674.98
B55	87.20	743.78	67.47	676.31	67.88	675.90	84.02	659.76	84.92	658.86
B56	102.40	742.23	85.95	656.28	85.44	656.79	86.55	655.68	86.60	655.63

[1] From 1996 Advanced Surveying and Mapping topographical map.

3.2.3 Dolomite Well Water

Ten wells cased into the dolomite bedrock are sampled to monitor the movement of hydrogen-3 in this aquifer. Most of the dolomite wells are located north of Plot M and east of the Red Gate Woods North Well (#5160), as shown in Figure 3.7.

Samples were collected from the dolomite wells quarterly. All samples were analyzed for hydrogen-3 and the results are shown in Table 3.9. Water levels were also measured in the dolomite wells and these measurements are in Table 3.10. Since these wells are cased in the dolomite aquifer, which is much deeper and not affected as much by drought, the groundwater elevations decreased less than what was observed in the shallow glacial till wells. The groundwater elevations in these wells were consistent with historical measurements in the wells and support the conclusion in the 1994 IT report[38] that groundwater in this area is moving to the northwest towards the Des Plaines River Valley.

The results of the hydrogen-3 analyses of the dolomite wells are consistent with concentrations measured in the past. All of the dolomite wells had low but measurable hydrogen-3 concentrations. The highest hydrogen-3 levels were in dolomite well D15. Figure 3.8 shows the hydrogen-3 concentrations in DH15 since 1990, which have been essentially stable since 1997. The presence of hydrogen-3 in these wells is supported by the 1979 USGS investigation[39] that indicated a hydrogen-3 plume underlies the stream which flows from Plot M and passes to the northeast of these wells (see Section 3.2). The plume has spread downward as well as downgradient, resulting in small amounts of hydrogen-3 in the dolomite. One other dolomite well with elevated hydrogen-3 is D03, which is immediately downgradient from Plot M. Previous analyses of soil core samples[39] indicated the presence of hydrogen-3 down to the drift-dolomite interface near D03. In any case, all of the dolomite wells were well below the Class 1 Groundwater Quality Standard of 20 nCi/L.

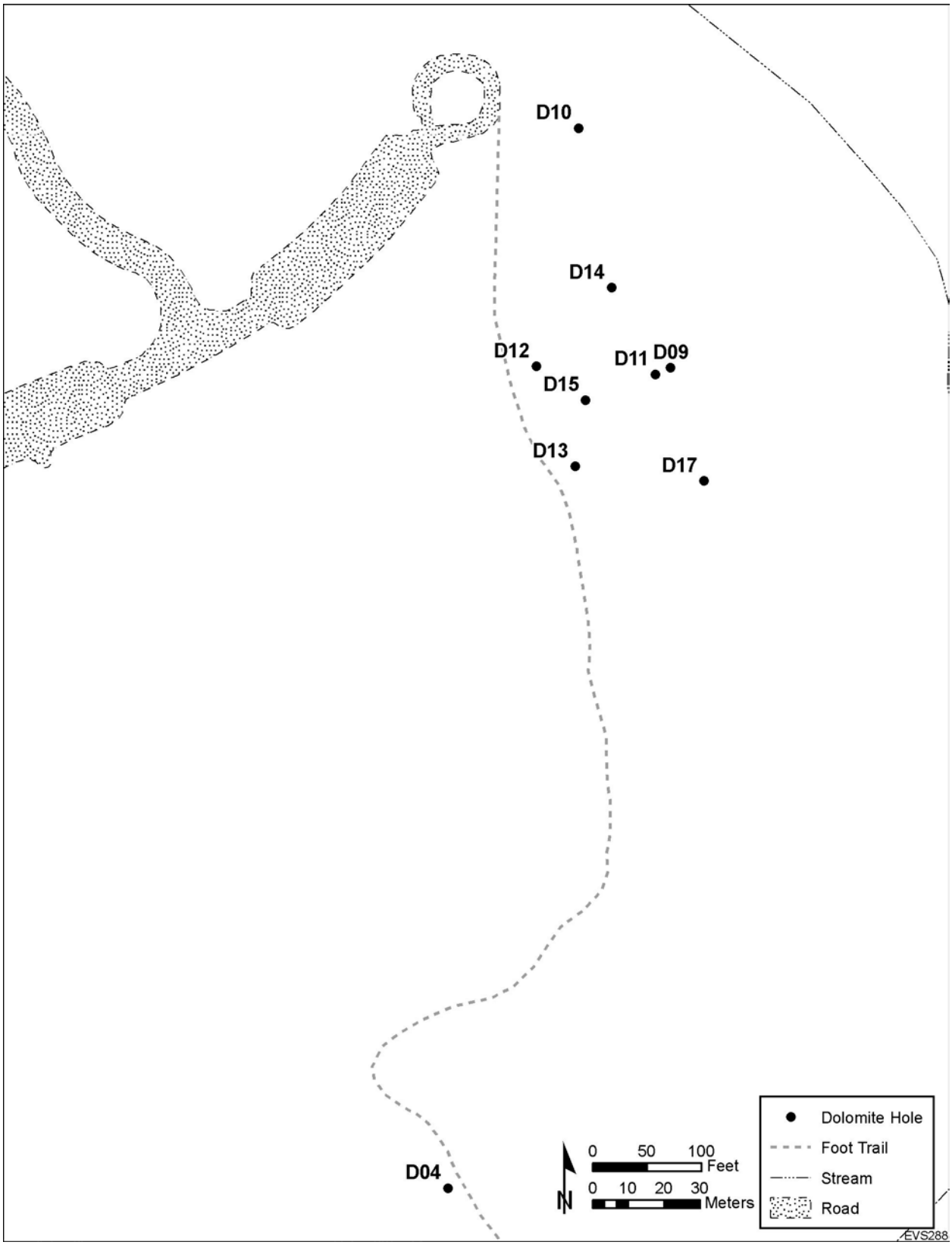

Figure 3.7 Locations of Dolomite Wells North of Plot M

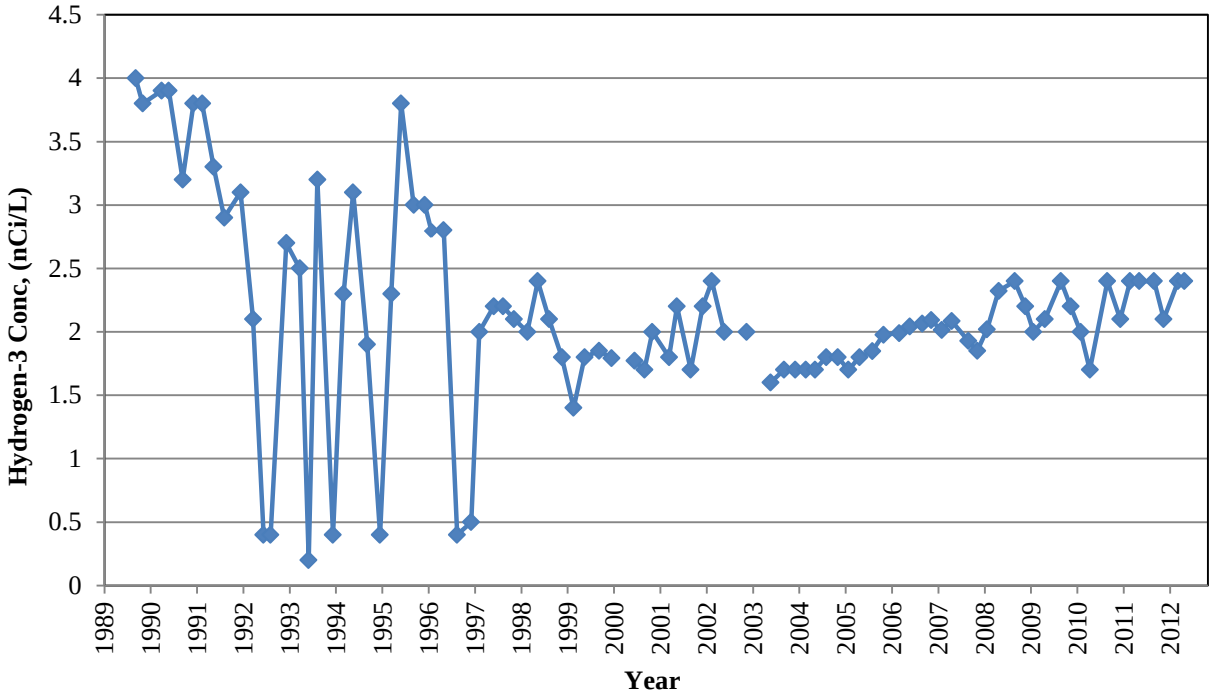

Figure 3.8 Hydrogen-3 Concentrations in Dolomite Well DH15

Table 3.9

Hydrogen-3 Content of Dolomite Well Water, 2012
(Concentrations in nCi/L)

Dolomite Well Number	Date Collected			
	March 7	May 21	September 12	November 1
D03	1.1	0.9	0.9	0.9
D04	0.7	0.7	0.6	0.7
D09	0.3	0.3	0.2	0.3
D10	0.7	0.7	0.7	0.7
D11	1.0	0.9	0.8	0.9
D12	1.1	0.7	1.0	1.0
D13	0.8	1.0	0.9	0.9
D14	0.9	0.9	0.7	0.7
D15	2.5	2.8	2.8	2.8
D17	0.3	0.3	0.3	0.3

Table 3.10

Water Level Measurements in Dolomite Wells, 2012

Well Number	Ground Surface Elevation (ft AMSL)	Top of Casing Elevation (ft AMSL)[1]	Date Measured: March 7		May 21		September 12		November 1	
			Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation	Depth to Water	Water Surface Elevation
D03	678.10	679.50	98.34	581.16	97.96	581.54	99.25	580.25	99.35	580.15
D04	673.80	674.60	93.54	581.06	93.21	581.39	94.55	580.05	94.55	580.05
D09	655.61	656.30	72.62	583.68	72.11	584.19	73.35	582.95	73.39	582.91
D10	644.66	646.10	63.85	582.25	64.72	581.38	66.12	579.98	65.18	580.92
D11	655.36	656.90	75.94	580.96	75.85	581.05	77.23	579.67	77.20	579.70
D12	650.34	651.60	76.98	574.62	76.90	574.70	78.36	573.24	78.36	573.24
D13	658.10	659.20	77.61	581.59	77.52	581.68	79.04	580.16	78.91	580.29
D14	651.43	653.20	71.99	581.21	72.00	581.20	73.40	579.80	73.28	579.92
D15	659.14	660.80	79.62	581.18	79.61	581.19	81.01	579.79	80.97	579.83
D17	654.35	656.00	74.89	581.11	74.91	581.09	76.18	579.82	76.15	579.85

[1] From 1994 IT Study Report. Ground surface elevation for D12 through D17 estimated from TOC elevations.

3.2.4 Former Picnic Wells

Sampling was conducted quarterly at two disabled forest preserve picnic wells (#5160 and #5159) located north of Plot M as shown in Figure 1.2. The Red Gate Woods North Well (#5160) was disabled in 1999 by removing the pump handle because of high fecal coliform levels. The well opposite Red Gate Woods (#5159) is not usable as a water source since the pump handle has also been removed. All the samples were analyzed for hydrogen-3 and the results are listed in Table 3.11. The maximum and average hydrogen-3 concentrations since 1996 for wells #5160 and #5159 are presented in Table 3.12. The change in hydrogen-3 concentrations in these wells since 1992 is shown in Figure 3.9.

The 2012 samples collected from well #5159 contained concentrations of hydrogen-3 commonly seen during the last few years, though occasional spikes of much higher concentration have been seen. The hydrogen-3 concentrations in well #5160 found during 2012 were the highest since 1996. Figure 3.9 shows that there has been an increasing trend in the hydrogen-3 concentrations in this well over the last two years.

As discussed in Section 4, the potential radiation dose from hydrogen-3 was estimated for Well #5160 using a value equal to the Red Gate Woods North well maximum hydrogen-3 concentration. Assuming water with a maximum hydrogen-3 concentration of 2.1 nCi/L was the sole source of water for an individual, the annual dose from the hydrogen-3 would be 0.11 mrem. If an individual consumed one liter of this water, the dose would be 0.00015 mrem. In a similar way, the potential dose associated with hydrogen-3 in the Opposite Red Gate Woods well (#5159) was estimated. The dose from the maximum hydrogen-3 concentration, assuming this well was the sole water source, would be 0.039 mrem/y and the dose for a single liter of this water would be 0.00005 mrem. All doses are well below any applicable standard.

Table 3.11

Hydrogen-3 Content of Former Picnic Wells Near Site A/Plot M, 2012
(Concentrations in nCi/L)

Date Collected	Red Gate North 5160	Opposite Red Gate 5159
March 8	1.10	0.20
May 21	1.37	0.29
August 3	2.09	0.12
October 11	1.92	0.74
Average	**1.62**	**0.34**

Table 3.12

Annual Maximum and Average Hydrogen-3 Concentrations in the Red Gate Woods Wells
(Concentrations in nCi/L)

	Red Gate Woods North (#5160)		Opposite Red Gate Woods (#5159)	
Year	Maximum	Annual Average	Maximum	Annual Average
1996	2.19	1.56	0.55	0.33
1997	1.26	1.00	1.13	0.35
1998	1.23	1.03	0.72	0.47
1999	1.22	1.07	2.14	0.45
2000	1.54	1.33	2.20	0.70
2001	1.59	1.49	0.27	0.16
2002	1.47	1.04	3.17	0.45
2003	1.78	1.06	1.49	0.43
2004	1.08	1.00	0.34	0.17
2005	1.01	0.95	0.34	0.19
2006	1.14	1.06	2.63	1.11
2007	1.45	1.28	0.66	0.33
2008	1.24	0.33	0.32	0.26
2009	0.13	0.10	0.50	0.33
2010	0.28	0.19	0.51	0.34
2011	0.91	0.67	3.60	1.10
2012	2.10	1.60	0.74	0.34

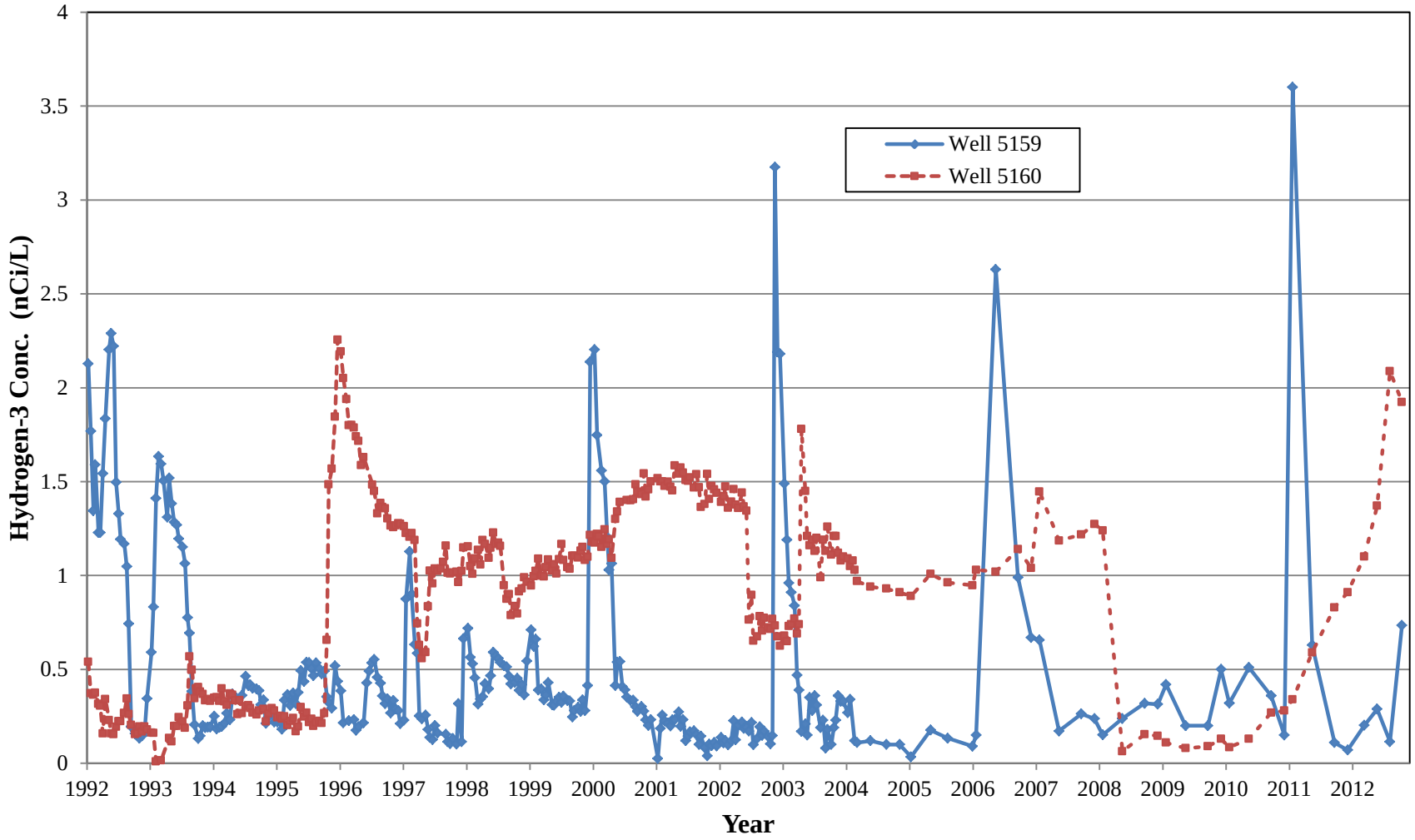

Figure 3.9 Hydrogen-3 Concentrations in Opposite Red Gate Woods (#5159) and Red Gate Woods North (#5160) Wells from 1992 Through 2012

4.0 SUMMARY OF POTENTIAL RADIATION DOSE AND RISK ESTIMATES

4.1 Dose Estimates

To put the risk associated with residual contamination into perspective, the potential radiation dose to a hypothetical individual was estimated. Taking a very conservative approach, it was assumed the hypothetical individual drank only water containing hydrogen-3 at the levels found at Plot M. The dose was estimated employing methodology prescribed in DOE guidance.[37] The committed effective dose equivalent from consumption of water was estimating by first calculating the total quantity of hydrogen-3 potentially ingested. The concentration of hydrogen-3 was multiplied by the general public water ingestion rate of 730 L/y.[41] This annual intake was then multiplied by the 50-year Committed Effective Dose Equivalent (CEDE) factor.[34] The CEDE for hydrogen-3 in water is 7.2×10^{-5} rem/μCi (based on the derived concentration standard of 1.9×10^{-3} μCi/mL). The highly conservative worst case scenario assumes that the hypothetical individual used water with the maximum hydrogen-3 concentration found in the seep (Location #6). The annual dose based on the maximum 2012 concentration of 118 nCi/L would be about 6.20 mrem/y. A slightly less conservative estimate of dose based on the annual average seep concentration (based on the two samples collected in 2012) of 111 nCi/L would be 5.8 mrem/y. Similar dose calculations were made assuming the water in former Red Gate Woods North Well (#5160) was the sole source of water consumed. In this case the maximum dose would be 0.11 mrem/y and the average dose would be 0.085 mrem/y. Similar estimates for the Opposite Red Gate Woods Well (#5159) are 0.039 mrem for the maximum concentrations and 0.018 mrem/y for the average concentration. The DOE dose limit for the public is 100 mrem/y, so even under highly conservative scenarios, the potential dose is well below DOE limits. These estimated doses are shown in Table 4.1.

A more realistic estimation was made based on the scenario of an occasional visitor to the Plot M area. Assuming a visitor drinks one liter of water from the surface stream or picnic well, the doses from this potential exposure were estimated and presented in Table 4.2. As defined here, the maximum potential total dose received by an occasional visitor is the sum of doses

from seep water plus dose from drinking water from the former Red Gate Woods North Well (#5160). This maximum dose would be 0.0087 mrem per visit.

In order to put the doses into perspective with other types of radiation exposure, comparisons can be made to annual average doses received by the public from natural or other generally accepted sources of radiation.[41] These are listed in Table 4.3. It is obvious that the magnitude of the doses potentially received near Plot M from residual radioactive substances remaining from work conducted in this area are insignificant compared to these sources.

4.2 Risk Estimates

Risk estimates of possible health effects from radiation doses to the public from Plot M have been made to provide another perspective in interpreting the radiation doses. Estimates for carcinogenic risk, the risk of contracting cancer from these exposures, are included in Table 4.1 and Table 4.2. Based on the BIER V report,[42] a dose of one mrem/y equates to an increased cancer risk of 7×10^{-7}. This conversion ratio is used to estimate incremental risk of contracting cancer from radiation exposure. For example, a carcinogenic risk of 10^{-7} would mean on average one additional cancer to 10,000,000 people exposed under the assumed exposure conditions. The EPA environmental protection standards are generally based on an acceptable risk between 10^{-4} and 10^{-6}. Examination of Table 4.1 indicates that even under the very conservative assumptions of sole source use of the water containing hydrogen-3 at Plot M at the annual average concentrations, the risk is less than the EPA standards. Table 4.2 shows that the hypothetical average surface water dose to an occasional visitor of 0.008 mrem would result in an increased cancer risk of about 5.6×10^{-9}. The incremental risk from exposure to radionuclides at Plot M can be compared to the risk associated with various life events. A few examples are shown in Table 4.4. The risk from the naturally-occurring sources of radioactivity listed in Table 4.3 is estimated to be about one additional cancer in a population of 8,000. Since the incremental risk under even the most conservative assumptions is so low, the monitoring program results have established that the impact of radioactivity at Site A/Plot M is very low and it does not endanger the health of those living in the area or visiting the site.

TABLE 4.1

Dose from Continuous Exposure to Hydrogen-3 at Selected Locations, 2012

Assumed Source	Maximum Conc. (nCi/L)	Maximum Dose (mrem/y)	Annual Average Conc. (nCi/L)	Annual Average Dose (mrem/y)	DOE Dose Limit (mrem/y)	Maximum Carcinogenic Risk
Surface Water						
Seep	118	6.2	111	5.8	100	4.1×10^{-6}
Well Water						
Red Gate Woods North (#5160)	2.1	0.11	1.6	0.085	100	6.0×10^{-8}
Opposite Red Gate Woods (#5159)	0.74	0.039	0.34	0.018	100	1.3×10^{-8}

TABLE 4.2

Estimates of Hydrogen-3 Exposures to a Casual Visitor to Plot M, 2012

Pathway	Quantity	Maximum Dose (mrem/visit)	Annual Average Dose (mrem/visit)	DOE Dose Limit (mrem/y)	Average Carcinogenic Risk
Surface Water					
Seep	One Liter	0.0085	0.0080	100	5.6×10^{-9}
Well Water					
Red Gate Woods North (#5160)	One Liter	0.00015	0.00012	100	8.2×10^{-11}
Opposite Red Gate Woods (#5159)	One Liter	0.00005	0.00002	100	1.7×10^{-11}

TABLE 4.3

Annual Average Dose Equivalent in the U. S. Population[1]

Source	Dose (mrem)
Natural Sources	
Radon	228
Internal (^{40}K and ^{226}Ra)	29
Cosmic	33
Terrestrial	21
Medical	
Computed Topography	147
Nuclear Medicine	77
Interventional Fluoroscopy	43
Conventional Radiography & Fluoroscopy	33
Consumer	13
Building Materials	
Commercial Air Travel	
Cigarette Smoking	
Mining and Agricultural	
Combustion of Fossil Fuels	
Highway and Road Construction Materials	
Glass and Ceramics	
Industrial	0.3
Nuclear-power Generation	
DOE Installations	
Decommissioning and Radioactive Waste	
Industrial, Medical, Educational, and Research Activities	
Contact with Nuclear-medicine Patients	
Security Inspection Systems	
Occupational	0.5
Medical	
Aviation	
Commercial Nuclear Power	
Industrial and Commercial	
Education and Research	
Government, DOE, and Military	
Total	**624**

[1]NCRP report No. 160.[41]

TABLE 4.4

Risk of Death from Various Events

Cause	Risk
Lightning Strike	5×10^{-8}
Tornado	1×10^{-7}
Flood	1×10^{-7}
Hurricane	2.5×10^{-7}
Drowning	8×10^{-6}
Air Travel	3×10^{-6}
Firearms	2×10^{-6}

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5.0 QUALITY ASSURANCE PROGRAM

All nuclear instrumentation is calibrated with standardized sources obtained from or traceable to the U. S. National Institute of Standards and Technology (NIST). The equipment is checked prior to the sample measurements with secondary counting standards to insure proper operation. Samples were periodically analyzed in duplicate or with the addition of known amounts of a radionuclide to check precision and accuracy. Argonne participates in the DOE Mixed-Analyte Performance Evaluation Program (MAPEP), a twice per year analysis of two different sample matrices containing known amounts of various radionuclides. The results of our participation in this program for 2011 are published in ANL-12/02.[43]

Many factors enter into an overall quality assurance program other than the analytical quality control discussed above. Representative sampling is of prime importance. Appropriate sampling protocols are followed for each type of sampling being conducted. Water samples are pre-treated in a manner designed to maintain the integrity of the analytical constituent. For example, samples for strontium-90 analysis are acidified immediately after collection to prevent hydrolytic loss of metal ions and filtered to reduce leaching from suspended solids. Samples for hydrogen-3 analysis do not require filtration or acidification.

The volume of water in the casing is determined by measuring the water depth from the surface. In accordance with EPA guidance[44], stagnant water is removed from the wells prior to sampling. From one to three times the well volume is removed. After the well refills with groundwater, it is sampled by bailing with a Teflon bailer. The Red Gate Woods dolomite wells are not purged since they are open boreholes drilled into the bedrock where stagnant water does not accumulate. All samples are placed in precleaned bottles, labeled, filtered, and preserved (strontium-90 samples). All sampling equipment is cleaned by field rinsing with Type II deionized water. The samples are transferred to the analytical laboratory along with a chain-of-custody transfer document.

5.1 Applicable Standards

The standard that is relevant to this study is the DOE Order 458.1 which established a total effective dose limit of 100 mrem/y.[37] The dose limit and dose calculation methodology are applicable to all media: surface water, deep holes, boreholes, and picnic well water. The EPA drinking water standard[35] is not applicable to the picnic wells since they do not meet the definition of a public water system. However, the EPA standard of 20 nCi/L for hydrogen-3 or the IEPA Class I groundwater standard of 8 pCi/L for strontium-90 may be useful for some comparison purposes.

5.2 Analytical Methods

The analytical methods used to obtain the data in this report are the same as those used to generate the results presented in ANL-12/02.[43]

5.3 Intercomparison Program

Starting in 2012, Argonne began a program of splitting a subset of the samples it collects with the Illinois Emergency Management Agency (IEMA). The IEMA operates a laboratory that conducts radiological analyses similar to Argonne. The duplicate set of samples is analyzed by both Argonne and the IEMA and the results are compared to ensure that comparable results are obtained.

6.0 REFERENCES

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