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SURVEILLANCE OF SITE A AND PLOT M

Report for 1990

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ABSTRACT

The results of the environmental surveillance program conducted at Site A/Plot M in the Palos Forest Preserve area for CY 1990 are presented. The surveillance program is the ongoing remedial action that resulted from the 1976-1978 radiological characterization of the site. That 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 program consists of sample collection and analysis of air, surface and subsurface water, and bottom sediment. The results of the analyses are used to 1) determine the migration pathway of water from the burial ground (Plot M) to the hand-pumped picnic wells, 2) establish if buried radionuclides other than hydrogen-3 have migrated, and 3) generally characterize the radiological environment of the area. Hydrogen-3 in the Red Gate Woods picnic wells was still detected this year, but the magnitude of the maximum concentration was significantly less than found earlier. A replacement well was installed in July 1988 in the Red Gate Woods area to provide a source of water for public use that was intended to be free of tritium and trace metals. Tritiated water continues to be detected in a number of wells, boreholes, dolomite holes, and a surface stream. For many years it was the only radionuclide found to have migrated in measurable quantities. Analyses since 1984 have indicated the presence of low levels of strontium-90 in water from a number of boreholes next to Plot M. The available data does not allow a firm conclusion as to whether the presence of this nuclide represents recent migration or movement that may have occurred before Plot M was capped. 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 or those living in the vicinity.

1.0 INTRODUCTION AND MONITORING

1.1 Site History

This report presents and discusses the surveillance data obtained during CY 1990. The surveillance program is the ongoing remedial action 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, which was part of the World War II Manhattan Engineer District Project, in the Palos Park Forest Preserve southwest of Chicago, IL. The Laboratory used two locations in the Forest Preserve: Site A, a 19-acre area that contained experimental laboratory and nuclear reactor facilities; and Plot M, a 150 ft x 140 ft area used for the burial of radioactive waste. These locations are shown in Figures 1.1 and 1.2. To assist in understanding this report, reference should be made to the previous comprehensive reports on this subject,^{1,2} which provide greater detail and illustrations on sampling locations and descriptive material and give the results through 1981, and to the annual reports for 1982,³ 1983,⁴ 1984,⁵ 1985,⁶ 1986,⁷ 1987,⁸ 1988,⁹ and 1989.¹⁰ Earlier data will not be repeated in this report, but reference will be 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, tritium recovery from irradiated lithium, and studies of the metabolism of radionuclides in laboratory animals. Radioactive waste and radioactively-contaminated laboratory articles from these studies were buried in 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, together with various pipes, valves, and building debris, were buried in place in 1956.

Burial of radioactive waste at Plot M began in 1943 or 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

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

Laboratory for disposal, but the waste buried in trenches was allowed to remain in place. Both the Site A and Plot M areas were decommissioned in 1956. 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.

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

The terminology used in previous reports is continued. A hole drilled and completed into the glacial till is called a borehole. The soil samples obtained from the borehole are called soil cores. Some boreholes have been cased and screened to form monitoring wells. Water from such wells is called borehole water. Test wells drilled into the dolomite bedrock are called dolomite holes or deep holes. Water from such wells is called dolomite water. The hand-pumped picnic wells, which are completed into or close to the dolomite bedrock, are called wells or picnic wells. They are identified by a location name or well number. Except for well #5160, these were in existence before this radiological and hydrological study of the area was begun.

The results of radioactivity measurements are expressed in this report in terms of picocuries per liter (pCi/L) and nanocuries per liter (nCi/L) for water, picocuries per cubic meter (pCi/m³) for air, and picocuries per gram (pCi/g) of the oven-dried (110°C) weight for sediment 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 till or 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 till 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 wetlands, ponds, and intermittent streams. When there is sufficient water, 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 (Fig. 1.2) and discharges into the Illinois and Michigan Canal. The groundwater in the glacial till 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 till, is controlled by two discharge areas, the Des Plaines River to the north and the Calumet Sag Canal to the south. Water usage in the area is confined to the hand-pumped picnic wells. These are open to the dolomite and are principally used in the warmer seasons.

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 33 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 7.9 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 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 (Fig. 1.2), although small numbers of individuals use the more remote areas of the Preserve.

2.0 SUMMARY

The results of the ongoing environmental monitoring and surveillance program at the Palos Park site for CY 1990 are presented in this report. Sample collection and analyses for radioactive and nonradioactive substances were conducted on air, surface and subsurface water, and bottom sediment. Water-vapor samples were collected over the streambed at two locations, one upstream and one downstream of the waste burial Plot M, and analyzed for tritium. Above ambient concentrations were found downstream of the Plot and are attributed to tritiated water leaching from the Plot and evaporating from the stream and transpiration from plants. The maximum dose from tritium in air to a hypothetical individual who spends all of his time at the downstream location would be 0.004 mrem/y, or 0.004% of the applicable U. S. Department of Energy (DOE) Radiation Protection Standard of 100 mrem/y for the general public.

Surface water samples collected from the stream that flows around Plot M showed the same tritiated water concentration pattern seen in the past. Concentrations were at the ambient level (< 0.2 nCi/L) upstream of the Plot, increased to 25-400 nCi/L adjacent to the Plot, then decreased to 10-20 nCi/L further downstream. Other radiochemical analyses of water and streambed sediment collected above and below Plot M indicated that there are slightly higher concentrations of strontium-90 in water and uranium and plutonium-239 in sediment downstream than from Plot M. For both the water and sediment samples, the concentrations were comparable to ambient or fallout levels.

The tritiated water concentrations in the borehole and dolomite hole water follow a pattern consistent with that observed in the past. The tritium concentration was highest in those boreholes nearest Plot M and downgradient of the Plot. Water from eight of 18 boreholes analyzed for strontium-90 contained concentrations greater than the detection limit of 0.25 pCi/L. The elevated strontium-90 levels (up to 6.6 pCi/L) found in some boreholes are probably from the Plot, since concentrations above 0.25 pCi/L have not been observed in the groundwater due to atmospheric fallout from previous nuclear weapons testing, and no other source is known.

Strontium-90 is a relatively mobile radionuclide and its presence in the borehole water is not unexpected and is probably due to migration that occurred before the Plot was capped. The strontium-90 results are consistent with those measured in the past.

Sampling of the forest preserve picnic wells continued. The maximum and average concentrations for the last few years for the Red Gate Woods North well (#5160) and the Red Gate Woods well (#5167) are presented in Table 2.1 and illustrated in Figure 2.1. The average tritium concentration in the well opposite Red Gate Woods (#5159) was twice the 1989 value and similar to the 1988 result. The maximum and minimum concentrations of #5159 were 2.1 nCi/L and less than 0.2 nCi/L, respectively. The other wells were all less than 0.2 nCi/L. The previous pattern of high tritium concentrations in the winter and low concentrations (less than the detection limit of 0.2 nCi/L) in the summer is not readily apparent. The maximum concentration (0.25 nCi/L) and the annual average (0.12 nCi/L) in the Red Gate Woods well (#5167) are significantly less than in earlier years. In the calculation of annual averages, all data as measured was retained in the data base and used to compute the average.

If water equal to the Red Gate Woods North well (#5160) average concentration of 0.22 nCi/L were the sole source of water for an individual, the annual dose from tritium would be 0.010 mrem based on the DOE limit. Compared to the U. S. Environmental Protection Agency (EPA) drinking water limit of 20 nCi/L,¹¹ this concentration is about 1% of the annual limit. Consumption of one liter of this water would produce a dose of 1.4×10^{-5} mrem. Table 4.1 provides a relative comparison of this calculated dose to natural or accepted 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 relative to the applicable standards.

TABLE 2.1

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

Year	5167 (Original Well)		5160 (Replacement Well)*	
	Maximum	Annual Average	Maximum	Annual Average
1982	9.2	4.8		
1983	3.0	2.2		
1984	2.7	1.2		
1985	2.5	1.0		
1986	3.4	1.3		
1987	3.3	1.6		
1988	0.48	0.18	0.30	0.19
1989	0.46	0.30	0.41	0.27
1990	0.25	0.12	0.52	0.22

*The replacement well (#5160) was installed in July 1988.

Figure 2.1 Trends in Tritium Concentrations in Red Gate Woods Well (#5167). (Concentrations in nCi/L)

3.0 MONITORING PROGRAM

The program is designed to monitor the elevated hydrogen-3 (as tritiated water) concentrations in some of the picnic wells in the Forest Preserve, determine the migration pathway of water from the burial ground to the wells, establish if other buried radionuclides or waste constituents have migrated, and characterize the radiological and non-radiological pollutant environment of the area. This is accomplished by analyses of water vapor samples and of water from wells, deep holes, boreholes, and surface streams in the area. Samples are collected from biweekly to annually, depending on past results and proximity to Plot M. During CY 1990, 326 samples were collected and 356 radiochemical analyses were performed. For the most part, individual results are presented in the tables, and compared to control, off-site, or upstream results. Where applicable, results are compared to appropriate standards such as the EPA drinking water standard¹¹ or the U. S. Department of Energy Radiation Protection Standard of 100 mrem/y.¹² The Site A/Plot M program follows the guidance for monitoring at DOE facilities.¹³ Although it is recognized that Site A/Plot M is not a DOE facility, the monitoring principles are applicable to this site.

The uncertainties associated with individual concentrations given in the tables are the statistical counting errors at the 95% confidence level. A few tables of tritium data do not contain these uncertainties. In such cases, the following uncertainties apply:

<u>Concentration (nCi/L)</u>	<u>Uncertainty (% of Conc.)</u>
0.2-1.0	25-5%
1-10	5-1%
> 10	1%

3.1 Air

Water vapor samples were collected over the surface of the stream next to Plot M, since this stream drains tritiated water leached from the Plot, and were analyzed for tritium to estimate the potential exposure from the

atmospheric pathway. Samples were collected upstream and downstream of Plot M and the results are given in Table 3.1. The concentrations were higher below Plot M than above, where the levels were similar to ambient concentrations of tritium in air of 0.20 pCi/m³.¹⁴ The spring and fall averages are calculated using the actual measured values even though in many cases, the results are below the detection limit.

Although water was not flowing in the stream during some of the sampling periods, above-ambient tritiated water vapor concentrations were observed below the Plot. As was also observed last year, the downstream air concentrations in the fall were lower than the spring values and are due to generally lower tritium stream concentrations in the fall. The dose to a hypothetical individual who breathed air continuously for one year at the maximum concentration of 7.9 pCi/m³ would be 0.004 mrem or 0.004% of the applicable DOE environmental dose limit of 100 mrem/y. This dose was calculated using the methodology specified in the DOE Order¹² for determining radiation exposures to members of the public in uncontrolled areas. The total quantity of a radionuclide inhaled, in microcuries (μ Ci), is obtained by multiplying the air concentration by the general public breathing rate of 8400 m³/y.¹⁵ This annual intake is then multiplied by the 50-year Committed Effective Dose Equivalent factor (CEDE) to obtain the dose. The CEDE for tritiated water vapor is 6.3×10^{-5} rem/ μ Ci (rem per microcurie).

3.2 Surface Water

Six sets of samples were collected from the stream that flows around Plot M. The sampling locations are shown in Figure 3.1. The samples were analyzed for tritiated water and the results are in Table 3.2. The same concentration pattern in the water flowing around Plot M was observed this year as in the past. Concentrations were low upstream of the Plot, increased as the stream flowed past the Plot, where it received tritiated water leaching out of the burial site, then decreased downstream due to dilution.

Using the methodology prescribed in the DOE guidance,¹² the committed effective dose equivalent for consumption of water can be calculated. The

TABLE 3.1

Concentrations of Tritiated Water Vapor Above the
Streambed Adjacent to Plot M, 1990
(Concentrations in pCi/m³)

Sampling Period	Location #1* (Upstream)	Location #9* (Downstream)
April 3 to April 6	< 0.5	2.2 ± 0.5
April 9 to April 12	< 0.5	1.7 ± 0.5
April 16 to April 19	< 0.5	4.0 ± 0.5
April 23 to April 26	< 0.5	7.9 ± 1.4
May 1 to May 4	< 0.5	3.4 ± 0.6
Spring Average	0.2 ± 0.2	3.8 ± 2.2
September 24 to September 27	< 0.5	4.1 ± 1.1
October 1 to October 4	< 0.5	1.9 ± 1.0
October 8 to October 11	< 0.5	< 0.5
October 22 to October 25	0.6 ± 0.5	1.3 ± 0.6
October 29 to November 1	< 0.5	0.8 ± 0.8
Fall Average	0.2 ± 0.3	1.6 ± 1.4

*See Figure 3.1

Figure 3.1 Surface Water Sampling Locations Near Plot M

TABLE 3.2

Tritiated Water Content of Stream Next to Plot M, 1990
(Concentrations in nCi/L)

Location Number*	Date Collected					
	January 17	March 15	May 9	July 23	October 11	November 29
1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
2	< 0.2	0.4 ± 0.1	1.2 ± 0.1	1.0 ± 0.1	0.6 ± 0.1	0.2 ± 0.1
3	1.9 ± 0.1	13.9 ± 0.2	78.2 ± 0.5	27.6 ± 0.3	10.5 ± 0.2	10.1 ± 0.2
4	1.6 ± 0.1	12.8 ± 0.2	70.1 ± 0.5	22.7 ± 0.3	5.7 ± 0.2	8.5 ± 0.2
5	1.7 ± 0.1	11.5 ± 0.2	59.7 ± 0.5	19.3 ± 0.2	4.0 ± 0.1	7.9 ± 0.2
6 (Seep)	59.8 ± 0.5	326.4 ± 1.1	366.2 ± 1.2	241.8 ± 0.9	79.4 ± 0.5	153.2 ± 0.8
7	4.6 ± 0.2	18.7 ± 0.3	50.7 ± 0.4	43.7 ± 0.4	8.4 ± 0.2	13.0 ± 0.2
8	2.7 ± 0.1	52.5 ± 0.4	75.9 ± 0.5	45.4 ± 0.4	4.7 ± 0.2	25.5 ± 0.3
9	4.2 ± 0.1	27.5 ± 0.4	51.1 ± 0.4	40.8 ± 0.4	6.3 ± 0.2	14.0 ± 0.2
10	4.3 ± 0.1	20.0 ± 0.3	27.3 ± 0.3	12.4 ± 0.2	4.7 ± 0.2	10.6 ± 0.2
11	4.3 ± 0.1	13.6 ± 0.3	15.1 ± 0.2	8.2 ± 0.2	2.4 ± 0.1	7.2 ± 0.2
Outfall**	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

* See Figure 3.1

** I & M Canal

total quantity of an ingested radionuclide is obtained by multiplying the water concentration by the general public water ingestion rate of 730 L/y.¹⁵ This annual intake is then multiplied by the 50-year Committed Effective Dose Equivalent factor (CEDE). The CEDE for tritium in water is 6.3×10^{-5} rem/ μ Ci. If a hypothetical individual used water with the same tritium concentration as found in the seep (Location #6) as his sole source of water, the annual dose based on the maximum 1990 concentration of 366 nCi/L would be about 17 mrem/y, the dose would be 9 mrem/y based on the annual average seep concentration of 204 nCi/L. The DOE dose limit to the public is 100 mrem/y. Using the same calculations for concentrations at Location #9, the maximum concentration of 51.1 nCi/L would produce 2.4 mrem/y and the 1990 average concentration of 24.0 nCi/L would give a dose of 1.1 mrem/y. Consumption of one liter of water with the same annual average concentration as at Location #9 would produce a dose of 0.002 mrem/y.

Large volume (20 liter) water samples were collected on April 3, 1990, and November 29, 1990, from this stream above Plot M at Location #1 and from below Plot M at Location #9. These samples were analyzed for very low concentrations of radionuclides to determine if any detectable amounts had migrated out of Plot M and entered this surface stream. The results are given in Table 3.3. In addition to hydrogen-3, there are slightly elevated concentrations of strontium-90 and uranium at the downstream location. Strontium-90 has been found in the past in Borehole #6 in Figure 3.2, between Plot M and the stream, and its presence in the stream would be another indicator of possible migration of this radionuclide.

3.3 Subsurface Water

3.3.1 Borehole Water

A number of the boreholes drilled in the Plot M area (Fig. 3.2) were cased with plastic pipe and screens were installed (piezometers) to serve as sampling points within the glacial till. Water samples were collected and water level measurements were made in these boreholes approximately bi-monthly, weather permitting. Each borehole was emptied of water and allowed to recharge before sampling. The shallow boreholes responded to the spring

TABLE 3.3

Radioactivity Content of Stream Next to Plot M, 1990
(Concentrations in pCi/L)

Constituent	Date Collected	Location #1* (Upstream)	Location #9* (Downstream)
Total Alpha**	April 3	1.06 ± 0.17	0.99 ± 0.19
	November 29	0.69 ± 0.13	0.70 ± 0.16
Total Beta**	April 3	5.21 ± 0.23	6.15 ± 0.26
	November 29	2.81 ± 0.19	5.76 ± 0.25
Hydrogen-3	April 3	< 200	$4.88\text{E}+04 \pm 513$
	November 29	< 200	$1.40\text{E}+04 \pm 279$
Strontium-90	April 3	0.76 ± 0.05	1.23 ± 0.06
	November 29	0.55 ± 0.04	1.10 ± 0.06
Uranium-234	April 3	0.32 ± 0.09	0.58 ± 0.11
	November 29	0.51 ± 0.10	0.55 ± 0.13
Uranium-238	April 3	0.17 ± 0.07	0.65 ± 0.12
	November 29	0.39 ± 0.03	0.67 ± 0.15
Neptunium-237	April 3	< 0.001	0.001 ± 0.001
	November 29	< 0.001	0.001 ± 0.001
Plutonium-238	April 3	< 0.001	< 0.001
	November 29	< 0.001	0.016 ± 0.002
Plutonium-239	April 3	0.001 ± 0.001	< 0.001
	November 29	< 0.001	0.002 ± 0.001
Americium-241	April 3	0.002 ± 0.001	0.001 ± 0.001
	November 29	0.001 ± 0.001	0.002 ± 0.001
Curium-242 and/or	April 3	0.001 ± 0.001	< 0.001
	November 29	< 0.001	< 0.001
Curium-244 and/or Californium-252	April 3	0.001 ± 0.001	< 0.001
	November 29	0.001 ± 0.001	0.001 ± 0.001

* See Figure 3.1

** Non-volatile

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

precipitation as indicated by an increase in water levels followed by a drop during summer and fall when moisture was used for plant growth. The water levels in the deeper boreholes (> 100 ft) were relatively constant throughout the year. As in past years, some boreholes were occasionally dry.

All the water samples were analyzed for tritiated water and the results are collected in Table 3.4. Borehole #11 contains a nest of piezometers at three depths; 39 feet, 68 feet, and 124 feet. The piezometer at 68 feet was dry most of the year. The principal purpose of this arrangement is to obtain water level measurements at different depths to determine the vertical gradient of the hydraulic head. Another piezometer (Borehole #40) was installed next to Borehole #4 late in 1987.

The tritium concentrations varied more widely than in past years. In 1988, tritium concentration in Borehole #2 increased by about a factor of ten near the end of the year. The concentration remained at this level through the first two sampling periods in 1989 and then decreased to the former level. About the same time the tritium concentration in Borehole #2 was decreasing, the concentration in Borehole #4 was increasing by about a factor of four. During 1990, the concentration in Borehole #4 remained elevated, but the concentration in Borehole #5 did not increase. In addition, Boreholes #6, #9, and #26 show low concentrations in the spring, probably due to dilution by precipitation recharge, and higher concentrations later in the year.

In the 40-foot deep boreholes, low tritium concentrations correlate with high water levels, apparently a dilution phenomenon. The measured water levels in the boreholes are in Table 3.5. Since the measurement of the water levels is made relative to a benchmark at the top of the well casing, a decrease in numerical value indicates a rise in water level and dilution of the tritiated water. Higher tritiated water concentrations correlate with higher tritium concentrations in the soil cores obtained when the boreholes were constructed.

A DOE Tiger Team evaluating the Argonne National Laboratory environment, safety, and health programs also reviewed the Site A/Plot M monitoring

TABLE 3.4

Tritium in Borehole Water, 1990
(Concentrations in nCi/L)

Borehole Number	Depth (ft)	Date Collected				
		January 24	March 20	May 23	October 30	November 1
1	40	1427	1363	1273	1573	1534
2	40	293	223	196	416	411
3	40	4082	3331	3517	3368	3288
4	40	1468	1735	1983	1522	1833
5	40	108	87.9	87.1	89.5	67.0
6	40	52.9	4.6	7.7	207	254
8	40	0.2	< 0.2	0.5	< 0.2	0.3
9	40*	745	1160	1492	2898	15160
10	40*	-	1326	951	6490	6403
11	39	1372	15.7	68.8	783	1174
11	124	11.4	11.3	10.1	28.7	16.4
24	126	6.5	3.6	16.4	11.4	5.4
26	60	21.2	6.0	74.4	879	955
28	60	182	175	182	174	181
35	110	312	651	1192	1150	157
36	127	525	249	401	682	677
40	25	1720	619	366	454	624

* Slant hole drilled at 45° to a depth of 40 ft below the surface

TABLE 3.5

Water Level Measurements in Boreholes Near Plot M, 1990
 (Units of feet below the benchmark at the top of the well)

Borehole Number	Depth (ft)	Date Measured			
		January 24	March 20	May 23	October 30
1	40	39.97	38.76	31.81	37.18
2	40	25.62	21.13	20.98	26.31
3	40	36.79	34.74	30.85	31.66
4	40	20.55	12.14	10.33	16.71
5	40	25.51	22.76	20.78	22.73
6	40	15.39	9.03	9.66	31.34
8	40	35.44	34.80	29.70	35.70
11	39	23.65	16.50	18.46	25.07
11	68	Dry	Dry	52.83	Dry
11	124	104.71	104.87	103.94	104.53
24	125	81.31	79.39	81.35	81.46
26	60	49.02	44.57	42.44	45.69
28	60	55.05	55.03	52.81	53.27
35	110	92.80	94.03	93.21	93.48
36	127	105.20	103.83	103.78	104.92
40	25	0.64	0.00	0.00	3.35

program. The Tiger Team found that the current sample collection method for the boreholes was inconsistent with the EPA guidance. The EPA protocols require that a monitoring well be purged and a sample collected within the first two hours or the sample may not be representative of the groundwater.

Geological conditions at Plot M make it very difficult to follow the EPA guidance. Many of the monitoring wells at Plot M have been placed in clay-rich units with very low permeability. Recharge to these monitoring wells over a two-hour period will be insufficient to obtain an appropriate volume (up to one gallon) of water to conduct the analytical tests. The EPA criteria applies to situations where sensitive constituents such as volatile organic chemicals are of concern. Groundwater analyses at Plot M are for radioactive constituents, especially tritium which is less sensitive to chemical or physical loss from the groundwater than the volatile organic chemicals.

In order to determine if the results were significantly different when using the EPA guidance, the set of samples collected on October 30, 1990, was done without purging the monitoring wells. The wells were then purged and another set of samples was collected as soon as a sufficient volume of water was available as required by the EPA guidance. The results of the tritium analyses are listed in Table 3.4. The before purging set is the October 30, 1990, set and the after purging set is the November 1, 1990, set.

The tritium data obtained from the groundwater samples before and after purging each monitoring well were compared using the Wilcoxon signed rank test. This test is a nonparametric statistical test used to evaluate dependent data pairs. Based on the results of this analysis, no significant difference is suggested due to the purging of the monitoring wells from the application of this test at the 78% level of significance. In the statistical analysis required for Resources Conservation and Recovery Act (RCRA) facilities, a 1% or 5% level of significance is considered sufficient to prove no difference in water quality in monitoring wells. Based on this study, the previous analytical data that have been collected have not been biased by inadequate sampling procedures. No significant differences in

tritium concentrations occur in groundwater at Plot M due to purging of the groundwater prior to sampling the monitoring wells.

In addition to the tritium comparison, water levels were measured daily on all the wells after they had been purged to collect information needed to determine recharge rates. Water-level data were plotted on semi-logarithmic paper to evaluate the hydraulic conductivity of the materials surrounding the monitoring wells and to estimate the recharge rates. The Hvorslev method¹⁷ was used to evaluate the data. Only three monitoring wells (#2, #35, and #40) recharged at a rapid rate and could be sampled within two hours of purging. The other monitoring wells typically took over 20 hours to recharge. Some monitoring wells (#1, #5, and #10) may require up to two weeks to recharge sufficiently after purging to obtain groundwater samples.

As part of a search for radionuclides other than tritium in the borehole monitoring wells, sets of large volume water samples were collected to obtain greater sensitivity in the analysis. One set of samples was collected in the spring on May 23, May 29, and June 6, 1990, and the fall set was collected on October 30, October 31, and November 1, 1990. Samples were collected from all boreholes that yielded sufficient water for analysis. All samples were analyzed for strontium-90 and the results are shown in Table 3.6. Strontium-90 concentrations greater than the detection limit of 0.25 pCi/L were found in eight of the 18 sampled boreholes. Levels above 0.25 pCi/L would not be expected in this water from fallout, and no other source is known. The highest strontium-90 concentrations were found in water from a slant hole (Borehole #9) which is under the buried waste, and the 1990 concentrations were similar to the 1989 concentrations. It should be noted that the borehole with one of the higher strontium-90 concentrations (Borehole #6) is between the buried waste and the stream that flows around Plot M. These data indicate small but measurable amounts of strontium-90 have migrated from the waste into the surrounding glacial till. As seen in Table 3.3, measurable strontium-90 concentrations were also found in the stream water below the Plot.

TABLE 3.6

Radiochemical Analyses of Borehole Water Samples Near Plot M, 1990
(Concentrations in pCi/L)

Borehole*	Date Collected	Strontium-90
1 (40')	May 23	< 0.25
	October 30	0.26 ± 0.08
2 (40')	May 23	0.32 ± 0.07
	October 30	< 0.25
3 (40')	May 23	< 0.25
	October 30	< 0.25
4 (40')	May 23	< 0.25
	October 30	< 0.25
5 (40')	May 23	< 0.25
	October 30	< 0.25
6 (40')	May 23	2.62 ± 0.12
	October 30	3.25 ± 0.13
8 (40')	May 23	< 0.25
	October 30	0.43 ± 0.14
9 (40')	May 23	6.65 ± 0.19
	October 30	3.28 ± 0.14
10 (40')	May 23	< 0.25
	October 30	< 0.25
11 (39')	May 23	1.31 ± 0.10
	October 30	2.62 ± 0.17
11 (68')	May 23	4.40 ± 0.16
11 (124')	May 23	< 0.25
	October 30	< 0.25
24 (125')	May 23	< 0.25
	October 30	0.35 ± 0.08
26 (60')	May 23	1.62 ± 0.10
	October 30	0.65 ± 0.08
28 (60')	May 23	< 0.25
	October 30	< 0.25
35 (110')	May 23	0.39 ± 0.08
	October 30	0.47 ± 0.08
36 (127')	May 23	< 0.25
	October 30	< 0.25
40 (25')	May 23	3.15 ± 0.14
	October 30	2.37 ± 0.12

* See Figure 3.2

3.3.2 Dolomite Hole Water

At the present time, 17 wells are cased into the dolomite zone to monitor the movement of any radionuclides in this aquifer. Most of the dolomite holes are located north of Plot M and east of the Red Gate Woods wells (#5160 and #5167), as shown in Figures 1.2 and/or 3.3. Four dolomite holes, DH 11 to DH 14, were installed in the fall of 1985 and three, DH 15 to DH 17 in the fall of 1986 by the U. S. Geological Survey (USGS), as part of a cooperative study of this site. Water was collected from the dolomite holes on the same schedule as the boreholes. All samples were analyzed for tritiated water and the results are in Table 3.7. Water levels were also measured in the dolomite holes and these measurements are in Table 3.8. Since the four wells installed in the fall of 1985 are located close to each other, the water level was only measured in DH 11 and assumed to be representative of the four.

The results of the tritiated water analysis of the dolomite holes are consistent with concentrations measured in the past. In all, ten of the dolomite holes had elevated tritiated water concentrations. The highest tritium levels are in the eight dolomite holes, DH 9 to DH 15 and DH 17, which are the furthest north and near the surface stream that flows next to Plot M (see Section 3.2). The distribution of tritium in these wells supports the USGS interpretation¹⁸ that a large tritium plume underlies the stream. The plume has spread downward as well as downgradient resulting in the current configuration of the tritium concentrations in the dolomite.

Four of the USGS holes have collapsed and water levels in them indicate they are open to glacial drift, not dolomite. These wells, which should not be considered as dolomite holes are: DH 6, DH 7, DH 8, and DH 9. However, DH 6 and DH 9 do provide useful tritium concentration data for the glacial drift just above the dolomite contact. The other dolomite hole with elevated tritium is DH 3, which is immediately downgradient from Plot M. Previous analyses of soil core samples indicated the presence of tritium down to the till-dolomite interface at DH 3.

Figure 3.3 Locations of Dolomite Holes North of Plot M

TABLE 3.7

Tritium in Site A Dolomite Wells, 1990
(Concentrations in nCi/L)

Dolomite Hole Number	Date Collected				
	January 15	March 15	May 9	October 5	November 30
1	-	< 0.2	< 0.2	< 0.2	< 0.2
2	-	< 0.2	< 0.2	< 0.2	< 0.2
3	-	1.9	1.6	1.5	1.8
4	-	< 0.2	< 0.2	< 0.2	< 0.2
5	-	< 0.2	< 0.2	0.2	< 0.2
6	1.5	3.0	2.8	1.8	1.5
7	-	< 0.2	< 0.2	0.4	< 0.2
8	-	< 0.2	< 0.2	< 0.2	< 0.2
9	11.4	11.1	9.0	6.6	6.5
10	7.1	6.1	5.6	5.6	5.7
11	10.4	7.9	7.0	4.7	4.9
12	4.9	4.7	4.4	5.9	6.0
13	5.2	4.6	4.5	4.0	4.2
14	9.2	7.6	-	-	-
15	5.0	4.0	3.8	3.9	3.9
16	0.3	< 0.2	< 0.2	< 0.2	< 0.2
17	2.0	1.5	1.5	1.5	1.6

TABLE 3.8

Water Level Measurements in Dolomite Holes Near Plot M, 1990
 (Units of feet below the benchmark at the top of the well)

Dolomite Hole Number	Date Measured				
	January 15	March 16	May 9	October 5	November 30
1	-	159.40	159.61	161.20	159.93
2	-	137.62	139.88	139.61	138.11
3	-	96.23	96.42	98.20	96.58
4	-	91.50	91.60	93.37	91.79
5	-	76.27	76.47	78.27	76.75
6	75.78	73.22	73.50	75.37	73.70
7	-	81.17	80.82	81.82	81.21
8	-	73.98	73.07	73.98	73.78
9	74.13	72.24	71.85	72.99	72.95
10	65.31	62.76	62.98	64.82	63.30
11	76.43	73.84	74.10	75.91	74.37
15	80.24	77.65	77.88	79.70	78.16
16	76.32	73.83	74.07	75.94	74.32
17	75.41	72.86	73.13	75.08	73.33

3.3.3 Well Water

In July 1988, a replacement well was installed in the Red Gate Woods picnic area (#5160) to replace the existing well (#5167) as a drinking water supply for visitors to this area. This will be referred to as the Red Gate Woods North well (#5160). This well was to be cased 20 feet into the dolomite to seal off fractures assumed to contain tritiated water. Previous experiments had indicated that the tritium moved at the till-dolomite interface and in the uppermost fractures in the dolomite. Extending the casing 20 feet into the dolomite and cementing the void between the casing and dolomite was expected to prevent tritium from entering the new well via these fractures. In addition, placement of a new pump mechanism on the new well was expected to eliminate the elevated lead concentrations found occasionally in the old well that resulted from corrosion of the old pump mechanism. The pump mechanism was removed from the old Red Gate Woods well to prevent its use by the public; however, the well was maintained as a sampling location for this monitoring program. In addition, the lower portion of the Red Gate Woods well (#5167) was filled with grout to seal the lower fracture and prevent communication of water with the new well.

Sampling was conducted throughout the year at the forest preserve picnic wells located north of Plot M and shown in Figure 1.2. These wells are located in the same dolomite as the previously discussed dolomite holes. Although sampling at the Guard Post well (#5215) was terminated in the middle of 1988, sampling was reinstated in May 1989 since this location provides a western limit on the tritium plume. All the samples were analyzed for tritiated water and the results are listed in Table 3.9.

The tritium concentrations in wells #5160 and #5167 have decreased to the level where the earlier pattern of high concentrations in the winter and low concentrations in the summer is not readily detectable. This decrease over the past few years is illustrated in Figure 3.4, which is a plot of the tritium concentrations in wells #5160, #5167, and #5159 for the past six years. The maximum tritium concentrations in the Red Gate Woods well (#5167) dropped from 3.3 nCi/L in 1987 to 0.25 nCi/L in 1990, while the average concentration dropped from 1.6 nCi/L in 1987 to 0.12 nCi/L in 1990.

TABLE 3.9

Tritiated Water Content of Wells Near Site A/Plot M, 1990
(Concentrations in nCi/L)

Date Collected	Red Gate North 5160	Red Gate 5167	Opposite Red Gate 5159	300 yds. East Red Gate 5158	95th & Archer 5157	Guard Post 5215
January 3	0.25	< 0.2	0.38	< 0.2	< 0.2	< 0.2
January 17	0.31	0.22	0.46	-	-	-
February 7	0.28	0.25	0.38	< 0.2	< 0.2	< 0.2
February 21	0.30	0.21	0.33	-	-	-
March 7	0.30	< 0.2	0.32	< 0.2	< 0.2	< 0.2
March 21	0.29	< 0.2	0.31	-	-	-
April 4	0.27	< 0.2	1.19	< 0.2	< 0.2	< 0.2
April 18	< 0.2	< 0.2	1.12	-	-	-
May 2	< 0.2	< 0.2	1.32	< 0.2	< 0.2	< 0.2
May 16	0.27	< 0.2	1.60	-	-	-
June 6	< 0.2	< 0.2	1.64	< 0.2	< 0.2	< 0.2
June 20	< 0.2	< 0.2	1.79	-	-	-
July 5	< 0.2	< 0.2	1.85	< 0.2	< 0.2	< 0.2
July 18	< 0.2	< 0.2	1.79	-	-	-
August 1	< 0.2	< 0.2	1.92	0.20	< 0.2	< 0.2
August 15	0.25	0.22	2.07	-	-	-
September 5	0.21	< 0.2	1.65	< 0.2	< 0.2	< 0.2
September 19	< 0.2	< 0.2	1.65	-	-	-
October 3	0.22	< 0.2	1.65	< 0.2	< 0.2	< 0.2
October 17	0.52	< 0.2	1.47	-	-	-
November 9	0.22	< 0.2	0.55	< 0.2	< 0.2	< 0.2
November 21	< 0.2	< 0.2	0.67	-	-	-
December 5	< 0.2	< 0.2	0.57	-	< 0.2	< 0.2
December 10	-	-	-	< 0.2	-	-
December 13	< 0.2	-	-	-	-	-
December 17	< 0.2	< 0.2	0.63	-	-	-
Average	0.22	0.12	1.14	< 0.2	< 0.2	< 0.2

Figure 3.4 Tritiated Water Concentrations in Red Gate Woods (#5167), Opposite Red Gate Woods (#5159), and Red Gate Woods North (#5160) Wells From 1985 Through 1990.

The annual average tritium concentrations are slightly higher in the new well (#5160) compared to the old well (#5167), see Table 2.1. The concentrations in #5160, although agreeing within the statistical uncertainty of the measurements and approaching the current levels of tritium in Lake Michigan water from residual fallout, were above the anticipated levels.

In an attempt to determine the subsurface source of the tritium, the Illinois District of the USGS was contracted to conduct packer tests within the new Red Gate Woods North well (#5160). The procedure was to use inflatable bladders to isolate ten-foot sections of the uncased dolomite and collect water samples for tritium analysis. The tritium concentrations may assist in determining what fractures are providing the water that is causing the elevated tritium in the well.

The tests were conducted in mid-December 1990. The initial phase was to use a three-arm caliper to determine the depth of any significant fractures. This test indicated that the well was cased to about 95 feet below the surface instead of the 105 feet requested in the original well drilling specifications. However, earlier caliper tests by the USGS and the well drillers log indicate that the well was cased to 105 feet. If the well were only cased to 95 feet, the major fracture in the dolomite at 96-98 feet should have been identified by the caliper test. The total depth of the hole was about 170 feet.

The packers were set up at ten-foot intervals and, where possible, at least three sample-interval volumes of water were purged from each sample interval and stable field parameters (pH, temperature, and specific conductance) were measured to assure that the sampled groundwater represented formation water. The tritium results are collected in the Table 3.10.

Assuming the well was actually cased to 105 feet, the uppermost packer interval was set within the casing. The next lower packer interval should bridge the bottom of the casing, and this implies very little if any leakage past the grout from the major fracture at 96-98 feet. The highest tritium concentration is between 154 and 164 feet below the surface. This interval brackets the fracture identified at 157 feet.

TABLE 3.10

Tritium Concentrations From Packer Tests Results
in Red Gate Woods North Well (#5160)
(Concentrations in nCi/L)

Date Collected	Depth (feet)	Hydrogen-3
12/18/90	85-95	0.22 ± 0.11
12/18/90	94-104	0.20 ± 0.11
12/18/90	104-114	0.16 ± 0.11
12/17/90	114-124	0.15 ± 0.11
12/14/90	124-134	0.22 ± 0.11
12/14/90	134-144	0.10 ± 0.10
12/13/90	144-154	0.09 ± 0.10
12/13/90	154-164	0.31 ± 0.11
12/13/90	164-171	0.26 ± 0.11

The fracture at 157 feet was also identified in caliper logs of DH 11, DH 12, DH 13, and DH 14. The other deepholes were not drilled deep enough to intersect this fracture. Since the bottom half of well #5167 (Red Gate Woods) was grouted, the fracture at 157 feet was sealed. The source of the tritium in well #5160 appears to be vertical migration of tritium down the deepholes at DH 11 to DH 14. Most of the flow exits the well into the major fracture at 96-98 feet, but some bypasses this fracture and exits at the lower fracture. The tritiated water then moves horizontally through this fracture, driven by pressure differentials, and is intersected by well #5160. The fractures have relatively low storage capacity and so are easily flushed out each season.

The other wells, although also downgradient from Plot M, are evidently too far from the Plot to show measurable tritium concentrations. Three of the picnic wells; #5159, #5157, and #5158 were not available to the public during the year. The Cook County Forest Preserve District had removed the pump handles due to high fecal coliform concentrations in the well water. A set of picnic well water samples was collected on April 12, 1990, and December 11, 1990, from the wells on the east and south sides of the Palos Forest Preserve. The sampled wells were #5162, #5031, #5188, #5153, #5154, #5226, #5021, #5193, #5232, and #5149 in Figure 1.2. All the tritium results were less than the detection limit of 0.2 nCi/L.

The Red Gate Woods North well (#5160) is the location which provides the greatest potential radiation exposure to the public in 1990. If water equal to the Red Gate Woods North well average concentration of 0.22 nCi/L were the sole source of water for an individual, the annual dose from the tritium would be 0.010 mrem. This may be compared with the EPA drinking water limit of a dose of 4 mrem/y, which results from the consumption of two liters of water per day or a concentration of 20 nCi/L.¹¹ If an individual consumed one liter of this water, the dose would be 1.4×10^{-5} mrem. These doses are very low compared to the current EPA limit.

In addition to tritiated water measurements, one set of water samples from the picnic wells was collected November 9, 1990, and analyzed for isotopic uranium, total alpha, total beta, strontium-90, and the transuranic

nuclides. The total alpha (0.9 to 4.3 pCi/L) and total beta (2.6 to 10.2 pCi/L) activities were in the normal range of concentrations found in other wells completed into the dolomite, the strontium-90 results were all less than the detection limit of 0.25 pCi/L and the transuranic nuclides were all less than the detection limit of 0.001 pCi/L. The uranium results are presented in Table 3.11. The range of concentrations is similar to that found previously.

Samples were collected quarterly from the Red Gate Woods north well (#5160) and analyzed for a number of inorganic constituents. The results are found in Table 3.12. Because this picnic well is used as a drinking water supply, the limits used were the State of Illinois concentrations of chemical constituents in drinking water.¹⁹ The constituents in Table 3.12 that do not have a specific limit are provided for completeness. Although the limits are exceeded for sulfate, this is probably due to natural causes. These concentrations are not unusual for dolomite water in northeast Illinois. Elevated levels of iron, lead, zinc, and some trace metals may be related to the decomposition of the well pump materials. There is no evidence that the source of the elevated inorganic constituents is from Plot M, since these metals are not found in the deepholes between Plot M and the Red Gate Woods wells.

3.4 Bottom Sediment

Bottom sediment samples were collected from the stream next to Plot M at Location #1 and Location #9 on April 3, 1990, and on November 29, 1990 (see Figure 3.1). Various radiochemical analyses were performed on these samples and the results are found in Table 3.13. The results are similar at all locations except that the cesium-137 and plutonium-239 are slightly elevated downstream. The concentrations are very low and in some cases similar to fallout levels of these radionuclides. For comparison to concentrations measured in the area away from the impact of any nuclear facilities, see the ANL-E Site Environmental Report for CY 1990.¹⁴

TABLE 3.11

Uranium Content of Well Water Near Plot M, 1990
(Concentrations in pCi/L)

Well Number*	Location	Date Collected			
		February 7	May 2	August 1	November 9
5160	Red Gate Woods North	0.08 ± 0.09	0.36 ± 0.19	0.27 ± 0.14	0.40 ± 0.14
5167	Red Gate Woods	0.12 ± 0.10	0.36 ± 0.16	1.64 ± 0.44	0.22 ± 0.13
5159	Opposite Entrance to Red Gate Woods	0.26 ± 0.14	0.34 ± 0.11	0.39 ± 0.12	1.07 ± 0.22
5158	300 yds NE of Entrance to Red Gate Woods	-	-	-	0.16 ± 0.08
5157	95th & Archer	-	-	-	2.78 ± 0.21
5215	Guard Post	-	-	-	0.25 ± 0.11

* See Figure 1.2

TABLE 3.12

Inorganic Constituents in Red Gate Woods North Well Water (#5160), 1990
(Concentrations in mg/L)

Inorganic Constituent	February	May	August	November	Limit**
Arsenic	< 0.0025	< 0.0025	< 0.0025	< 0.0025	
Barium	0.004	0.020	0.030	< 0.010	1.0
Beryllium	< 0.0002	< 0.0003	< 0.0003	< 0.005	-
Cadmium	< 0.0003	< 0.0003	< 0.0003	0.0067	0.01
Chloride	8	9	11	211	250
Chromium	< 0.004	< 0.004	< 0.004	0.016	0.05
Cobalt	< 0.03	< 0.03	< 0.03	< 0.05	-
Copper	0.056	0.041	0.024	0.039	-
Fluoride	0.080	0.220	0.200	0.162	-
Iron	12.52	20.95	18.97	21.00	-
Lead	0.11	0.10	0.08	0.02	0.05
Manganese	0.455	0.425	0.187	1.040	-
Mercury*	< 0.1	< 0.1	< 0.1	< 0.1	2.0*
Nickel	< 0.025	< 0.025	0.035	< 0.040	-
pH	7.7	-	7.1	7.1	-
Silver	< 0.0005	< 0.0005	< 0.0005	< 0.010	0.05
Sulfate	633	834	809	727	-
Thallium	< 0.010	< 0.010	< 0.010	< 0.010	
Vanadium	< 0.015	< 0.015	< 0.015	< 0.050	-
Zinc	1.93	11.50	24.25	17.10	-

*Concentrations in $\mu\text{g/l.}$

**State of Illinois concentrations of chemical constituents in drinking water.¹⁹ See text.

TABLE 3.13

Radioactivity Content of Streambed Next To Plot M, 1990
(Concentrations in pCi/g)

Radionuclide	Date Collected	Location #1* (Upstream)	Location #9* (Downstream)
Potassium-40	April 3	21.90 $\pm$ 0.78	23.36 $\pm$ 0.78
	November 29	21.46 $\pm$ 0.78	20.08 $\pm$ 0.79
Strontium-90	April 3	< 0.1	< 0.1
	November 29	0.23 $\pm$ 0.02	0.13 $\pm$ 0.02
Cesium-137	April 3	0.36 $\pm$ 0.02	0.52 $\pm$ 0.03
	November 29	0.16 $\pm$ 0.02	0.28 $\pm$ 0.03
Radium-226	April 3	2.75 $\pm$ 0.08	2.56 $\pm$ 0.08
	November 29	3.03 $\pm$ 0.09	1.71 $\pm$ 0.07
Thorium-228	April 3	1.17 $\pm$ 0.04	1.25 $\pm$ 0.04
	November 29	1.47 $\pm$ 0.04	1.10 $\pm$ 0.04
Thorium-232	April 3	1.16 $\pm$ 0.10	1.13 $\pm$ 0.10
	November 29	1.21 $\pm$ 0.10	0.90 $\pm$ 0.09
Uranium-234	April 3	1.43 $\pm$ 0.11	1.21 $\pm$ 0.10
	November 29	0.92 $\pm$ 0.07	0.89 $\pm$ 0.10
Uranium-238	April 3	1.40 $\pm$ 0.10	1.47 $\pm$ 0.12
	November 29	0.99 $\pm$ 0.08	0.90 $\pm$ 0.11
Plutonium-238	April 3	0.0005 $\pm$ 0.0001	0.0009 $\pm$ 0.0002
	November 29	0.0002 $\pm$ 0.0006	0.0006 $\pm$ 0.0007
Plutonium-239	April 3	0.0105 $\pm$ 0.0006	0.0439 $\pm$ 0.0017
	November 29	0.0065 $\pm$ 0.0021	0.0255 $\pm$ 0.0034
Americium-241	April 3	0.0039 $\pm$ 0.0009	0.0038 $\pm$ 0.0010
	November 29	0.0012 $\pm$ 0.0014	0.0041 $\pm$ 0.0013

* See Figure 3.1

4.0 SUMMARY OF POTENTIAL RADIATION DOSE ESTIMATES

The total dose received by an individual is the combination of the separate pathways. If a hypothetical person breathed air at the annual average tritium concentration of 2.7 pCi/m^3 from stream Location #9 and used water from the Red Gate Woods well as the sole source of water for an entire year, the annual dose would be 0.011 mrem. For the occasional visitor to Site A/Plot M, the average dose from spending one hour at Location #9 would be 2×10^{-7} mrem; the dose from drinking one liter of water from the Red Gate Woods well at the annual average concentration of 0.22 nCi/L would be 1.4×10^{-5} mrem; and consumption of one liter of water from Location #9 at the annual average concentration of 24.0 nCi/L would be 0.002 mrem.

In order to put the doses into perspective, comparisons can be made to annual average doses received by the public from natural or accepted sources of radiation. These are listed in Table 4.1. It is obvious that the magnitude of the doses potentially received near Site A/Plot M from residual radioactive substances remaining from work conducted in this area are insignificant compared to these sources. Therefore, the monitoring program results have established that radioactivity at Site A/Plot M is very low and does not endanger the health or safety of those living in the area or visiting the site.

TABLE 4.1

Annual Average Dose Equivalent
in the U. S. Population

Source	(mrem)
Natural Sources	
Radon	200
Internal (^{40}K and ^{226}Ra)	39
Cosmic	28
Terrestrial	28
Medical	
Diagnostic X-rays	39
Nuclear Medicine	14
Consumer Products	
Domestic Water Supplies, Building Materials, etc.	10
Occupational (medical radiology, industrial radiography, research, etc.)	1
Nuclear Fuel Cycle	< 1
Fallout	< 1
Other Miscellaneous Sources	< 1
Total	360

*NCRP Report No. 93.²⁷

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6.0 APPENDICES

6.1 Quality Assurance Program

All nuclear instrumentation is calibrated with standardized sources obtained from the U. S. National Institute of Standards and Technology (NIST), if available. If NIST standards were not available for particular nuclides, standards from the Amersham Corporation were used. 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. Intercomparison samples distributed by the Quality Assurance Branch of the EPA are analyzed regularly. In addition, our laboratory participates in the DOE Environmental Measurements Laboratory Quality Assurance Program, a semi-annual distribution of four different sample matrices containing various combinations of radionuclides. The results of our participation in both programs for 1990 are published in ANL-91/3.¹⁴

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 trace radionuclide analyses are acidified immediately after collection to prevent hydrolytic loss of metal ions.

6.2 Applicable Standards

The principal standard that is applicable to this study is the EPA drinking water standard¹¹ as applied to the forest preserve wells. All other water samples; surface stream, deep holes, and boreholes, are not drinking water supplies and therefore this standard does not apply. Since tritiated water is the only radionuclide identified in the Forest Preserve wells, the EPA limit of 20 nCi/L applies. The DOE Order¹² is applied to the other measurements. These effective dose equivalents are based on a radiation protection standard of 100 mrem/y.

6.3 Analytical Methods

The analytical methods used to obtain the data in this report are the same as those described in ANL-91/3.¹⁴

6.4 Acknowledgements

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