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Surveillance of Site A and Plot M Report for 1992

by N. W. Golchert

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SURVEILLANCE OF SITE A AND PLOT M

Report for 1992

by

Norbert W. Golchert

Environment and Waste Management Program

May 1993

Prepared for the U. S. Department of Energy
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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 1992 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 average and maximum concentrations were significantly less than found earlier. 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, using the picnic area, or living in the vicinity.

1.0 INTRODUCTION AND MONITORING

1.1 Site History

This report presents and discusses the surveillance data obtained during CY 1992. 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 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. 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] 1989,[10] 1990,[11] and 1991.[12] 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.

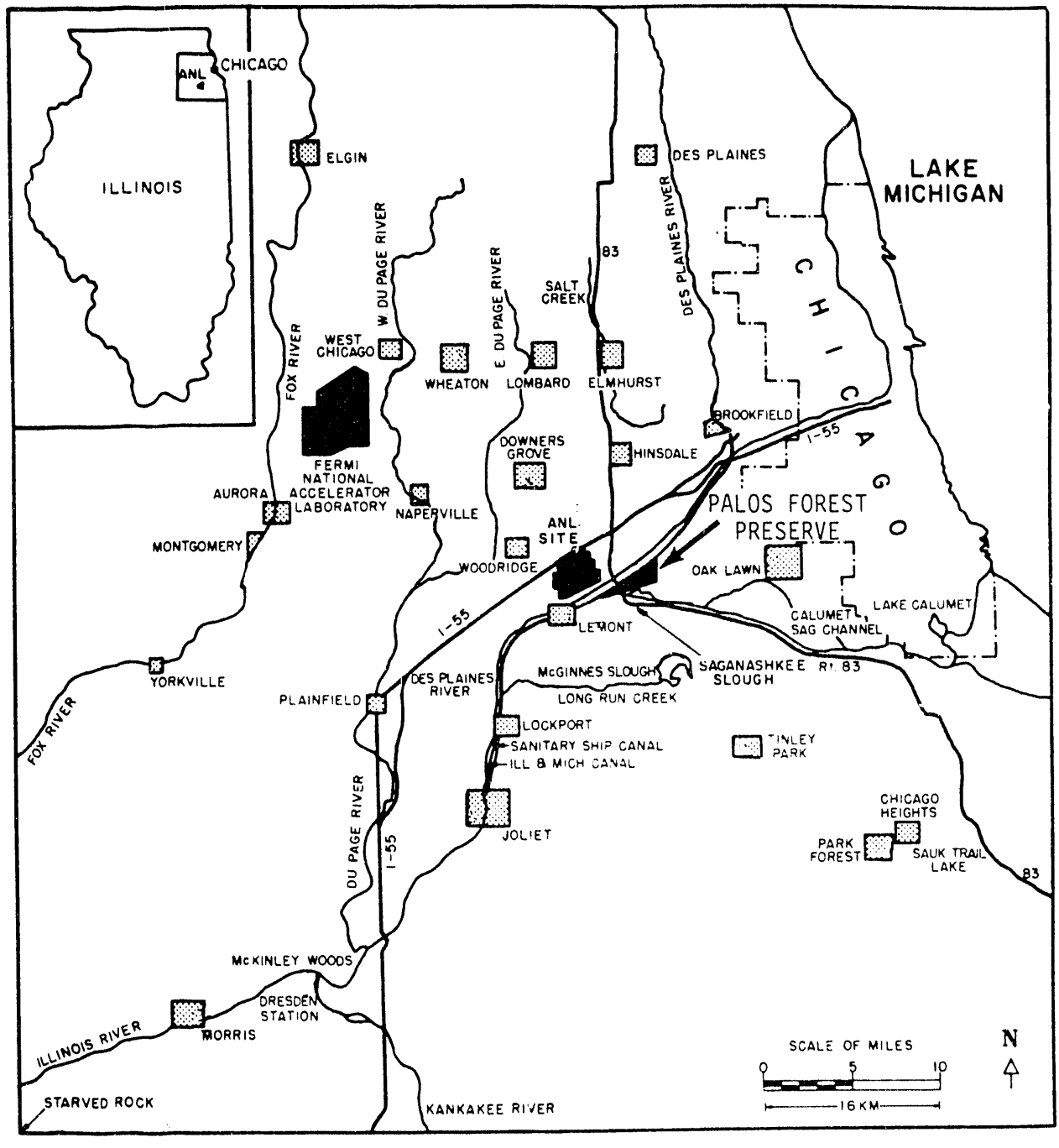

Figure 1.1 Location of Palos Forest Preserve on Chicago-Area Map

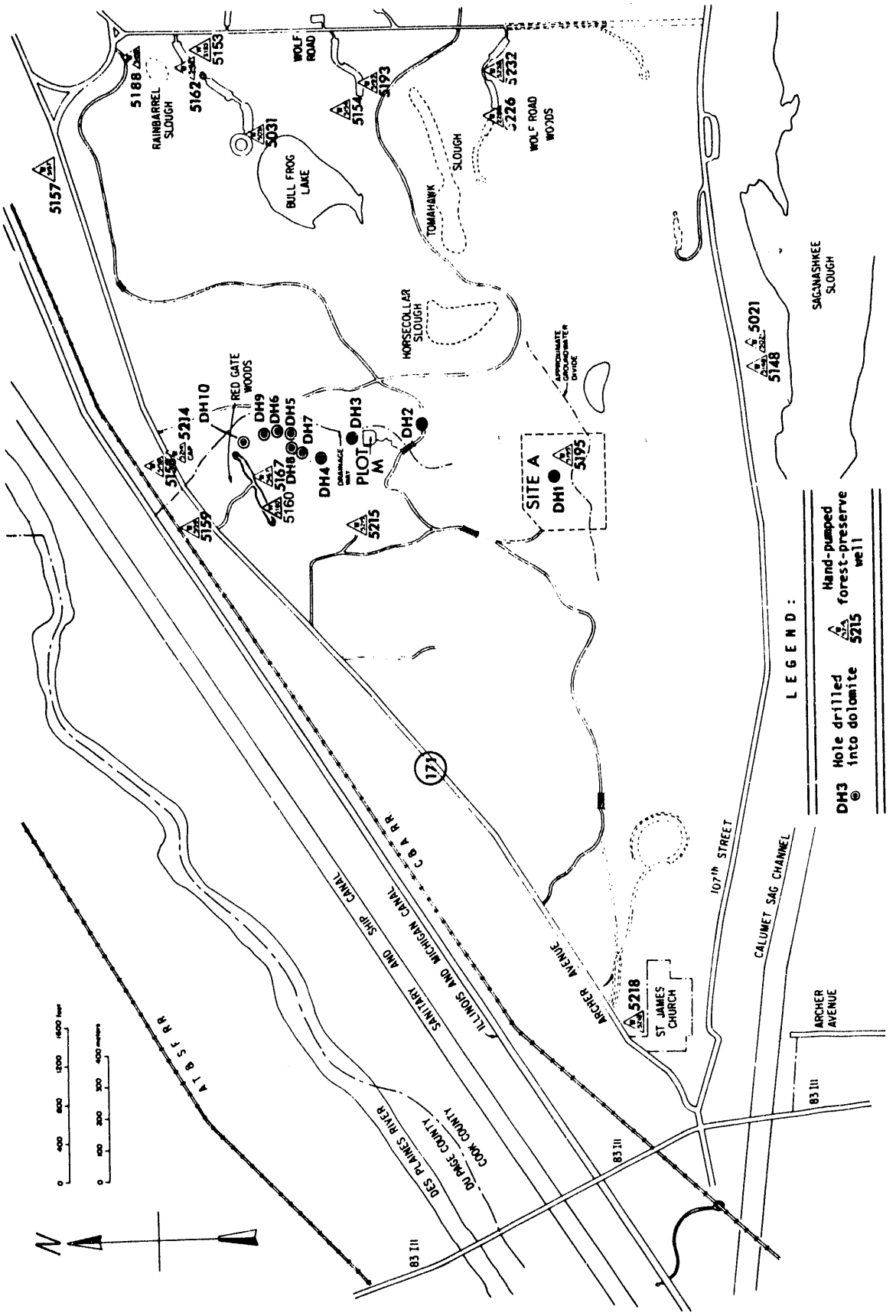

Figure 1.2 Palos Forest Preserve Showing Location of Site A/Plot M Dolomite Holes and Picnic Wells

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. 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 Forest Preserve site was conducted with special emphasis 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/m^3) for air, and picocuries per gram ($\mu Ci/g$) 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 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 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 (Fig. 1.2), although small numbers of individuals use the more remote areas of the Palos Forest Preserve.

2.0 SUMMARY

The results of the ongoing environmental monitoring and surveillance program at the Palos Forest Preserve site for CY 1992 are presented in this report. Sample collection and analyses for radioactive substances were conducted on air, surface and subsurface water, and bottom sediment, and for nonradioactive substances in subsurface water. 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 tritium concentrations were found downstream of the Plot and are attributed to tritiated water leaching from the Plot and evaporating from the stream. The maximum dose from tritium in air to a hypothetical individual who spends all of his time at the downstream location would be 0.008 mrem/y, or 0.008% of the applicable U. S. Department of Energy (DOE) Radiation Protection Standard of 100 mrem/y for the general public.[13]

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 (< 0.1 nCi/L) upstream of the Plot, increased to 180-1095 nCi/L at the seep adjacent to the Plot, then decreased to 10-40 nCi/L further downstream. Other radiochemical analyses of water and stream-bed sediment collected above and below Plot M indicated that there are slightly elevated concentrations of strontium-90 and uranium in water and cesium-137 and plutonium-239 in sediment downstream from Plot M. For both the water and sediment samples, the upstream 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 nine of 17 boreholes analyzed for strontium-90 contained concentrations greater than the detection limit of 0.25 pCi/L. The elevated strontium-90 levels (up to 9.58 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 shown in Figure 1.2 continued. In July 1988, the Red Gate Woods North (#5160) well was installed as a replacement drinking water supply for the Red Gate Woods (#5167) well. 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 maximum concentration (0.13 nCi/L) and the annual average (0.04 nCi/L) in the Red Gate Woods well (#5167) are significantly less than in earlier years. The maximum and average concentrations of the well opposite Red Gate Woods (#5159) were 2.3 nCi/L and 1.15 nCi/L, respectively. The other wells were all less than 0.1 nCi/L. The previous pattern of high tritium concentrations in the winter and low concentrations (less than the detection limit of 0.1 nCi/L) in the summer is not readily apparent for the Red Gate Woods well (#5167). In the calculation of annual averages, all data as measured were 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 0.25 nCi/L were the sole source of water for an individual, the annual dose from tritium would be 0.011 mrem using the DOE dose conversion factor. Although not applicable, compared to the U. S. Environmental Protection Agency (EPA) drinking water limit,[14] this concentration is about 1% of the annual limit of 20 nCi/L. Consumption of one liter of this water would produce a dose of 2×10^{-5} mrem. Table 4.3 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 relevant 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) Maximum	5167 (Original Well) Annual Average	5160 (Replacement Well)* Maximum	5160 (Replacement Well)* 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
1991	0.21	0.05	0.80	0.35
1992	0.13	0.04	0.54	0.25

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

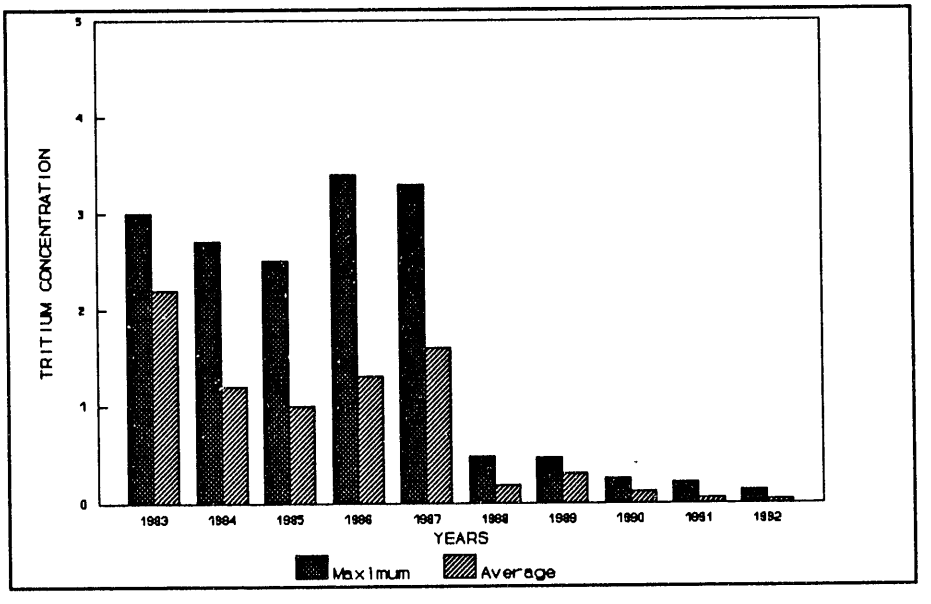

Figure 2.1 Trends in Tritium Concentrations in Red Gate Woods Well (#5167). (Concentrations in nCi/L)

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 Palos 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 analyzing water vapor samples and 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 1992, 333 samples were collected and 443 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 the U. S. Department of Energy Radiation Protection Standard of 100 mrem/y.[13] The Site A/Plot M program follows the guidance for monitoring at DOE facilities.[15] Although it is recognized that Site A/Plot M is not a DOE facility, the same 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:

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

The sensitivity for the measurement of tritium in water has been improved due to new instrumentation. The current detection limit is 0.1 nCi/L. The detection limit for tritium in air is 0.1 pCi/m^3.

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/m^3.[16] 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 14.3 pCi/m^3 would be 0.008 mrem or 0.008% of the applicable DOE environmental dose limit of 100 mrem/y. This dose was calculated using the methodology specified in the DOE Order[13] for determining radiation exposures to members of the public in uncontrolled areas. The total quantity of a radionuclide inhaled, in microcuries (μCi), is obtained by multiplying the air concentration by the general public breathing rate of 8400 m^3/y.[17] This annual intake is then multiplied by the 50-year Committed Effective Dose Equivalent (CEDE) factor to obtain the dose.[18] The CEDE for tritiated water vapor is 6.3×10^{-5} rem/μCi (rem per microcurie).

3.2 Surface Water

Three 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

TABLE 3.1

Concentrations of Tritiated Water Vapor Above the Streambed Adjacent to Plot M, 1992

(Concentrations in pCi/m^3)

Sampling Period	Location #1* (Upstream)	Location #9* (Downstream)
March 23 to March 26	0.3 ± 0.2	6.7 ± 0.4
March 30 to April 2	< 0.1	8.1 ± 0.3
April 6 to April 9	0.2 ± 0.3	14.3 ± 0.5
April 13 to April 16	< 0.1	6.1 ± 0.5
April 20 to April 23	< 0.1	11.8 ± 0.6
Spring Average	0.1 ± 0.2	9.4 ± 3.2
September 28 to October 1	< 0.1	3.7 ± 0.5
October 5 to October 8	< 0.1	2.1 ± 0.6
October 13 to October 16	0.5 ± 0.6	0.8 ± 0.6
October 20 to October 23	< 0.1	1.2 ± 0.5
October 27 to October 30	0.5 ± 0.4	1.0 ± 0.4
Fall Average	0.2 ± 0.3	1.8 ± 1.1

*See Figure 3.1

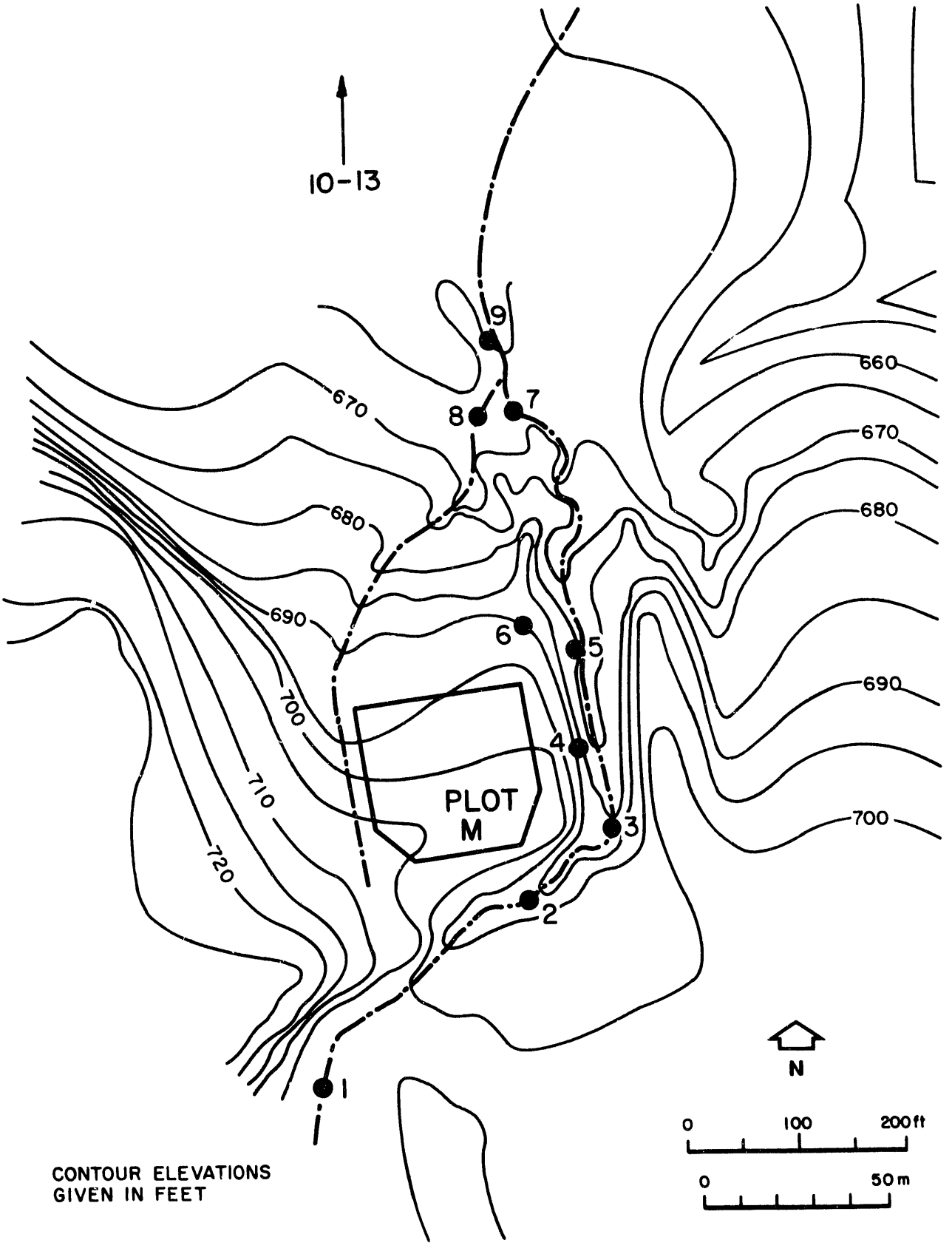

Figure 3.1 Surface Water Sampling Locations Near Plot M

TABLE 3.2

Tritiated Water Content of Stream Next to Plot M, 1992
(Concentrations in nCi/L)

Location Number*	Date Collected		
	January 2	March 18	December 15
1	< 0.2	< 0.1	< 0.1
2	0.3 ± 0.01	0.3 ± 0.1	16.7 ± 0.1
3	31.2 ± 0.2	41.8 ± 0.3	31.8 ± 0.2
4	38.1 ± 0.3	38.3 ± 0.3	48.3 ± 0.3
5	38.0 ± 0.3	35.0 ± 0.3	49.7 ± 0.3
6 (Seep)	180.2 ± 0.6	1095.0 ± 1.6	271.9 ± 0.8
7	42.7 ± 0.3	101.7 ± 0.5	92.3 ± 0.4
8	54.0 ± 0.3	52.9 ± 0.3	43.5 ± 0.3
9	43.8 ± 0.3	91.3 ± 0.4	78.7 ± 0.4
10	30.7 ± 0.2	59.3 ± 0.3	34.5 ± 0.2
11	17.6 ± 0.2	36.3 ± 0.3	12.4 ± 0.1
Outfall**	1.2 ± 0.1	2.2 ± 0.1	3.0 ± 0.1

*See Figure 3.1

**I&M Canal

water that leached out of the burial site, then decreased downstream due to dilution. The outfall sample was collected prior to discharge into the I&M Canal.

Using the methodology prescribed in the DOE guidance,[13] the committed effective dose equivalent for consumption of water can be calculated. The total quantity of an ingested radionuclide is obtained by multiplying the water concentration by the general public water ingestion rate of 730 L/y.[17] This annual intake is then multiplied by the 50-year Committed Effective Dose Equivalent (CEDE) factor.[18] The CEDE for tritium in water is 6.3×10^{-5} rem/μCi. 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 1992 concentration of 1095 nCi/L would be about 50 mrem/y and the dose based on the annual average seep concentration of 516 nCi/L would be 24 mrem/y. The DOE dose limit to the public is 100 mrem/y. Using the same calculations for concentrations at Location #9, the maximum concentration of 91.3 nCi/L would produce 4.2 mrem/y and the 1992 average concentration of 71.3 nCi/L would give a dose of 3.3 mrem/y. Consumption of one liter of water with the same annual average concentration as at Location #9 would produce a dose of 0.004 mrem/y.

Large volume (20 liter) water samples were collected on December 15, 1992, from this stream above Plot M at Location #1 and from below Plot M at Location #9. These samples were analyzed for the very low concentrations of other radionuclides that may be present 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. The elevated uranium concentrations are most likely due to surface contamination in the swale area northwest of Plot M[10] and may have been due to poor housekeeping during burial operations.

TABLE 3.3

Radioactivity Content of Stream Next to Plot M, 1992
(Concentrations in pCi/L)

Constituent	Date Collected	Location #1* (Upstream)	Location #9* (Downstream)
Total Alpha**	December 15	0.7 ± 0.2	2.1 ± 0.3
Total Beta**	December 15	4.2 ± 0.2	7.1 ± 0.3
Hydrogen-3	December 15	< 100	7.87×10^4 ± 371
Strontium-90	December 15	0.43 ± 0.03	1.39 ± 0.04
Uranium-234	December 15	0.16 ± 0.05	1.11 ± 0.13
Uranium-238	December 15	0.21 ± 0.06	1.12 ± 0.13
Neptunium-237	December 15	< 0.001	< 0.001
Plutonium-238	December 15	< 0.001	< 0.001
Plutonium-239	December 15	< 0.001	< 0.001
Americium-241	December 15	< 0.001	< 0.001
Curium-242 and/or Californium-249	December 15	< 0.001	< 0.001
Curium-244 and/or Californium-252	December 15	< 0.001	< 0.001

*See Figure 3.1

**Non-volatile

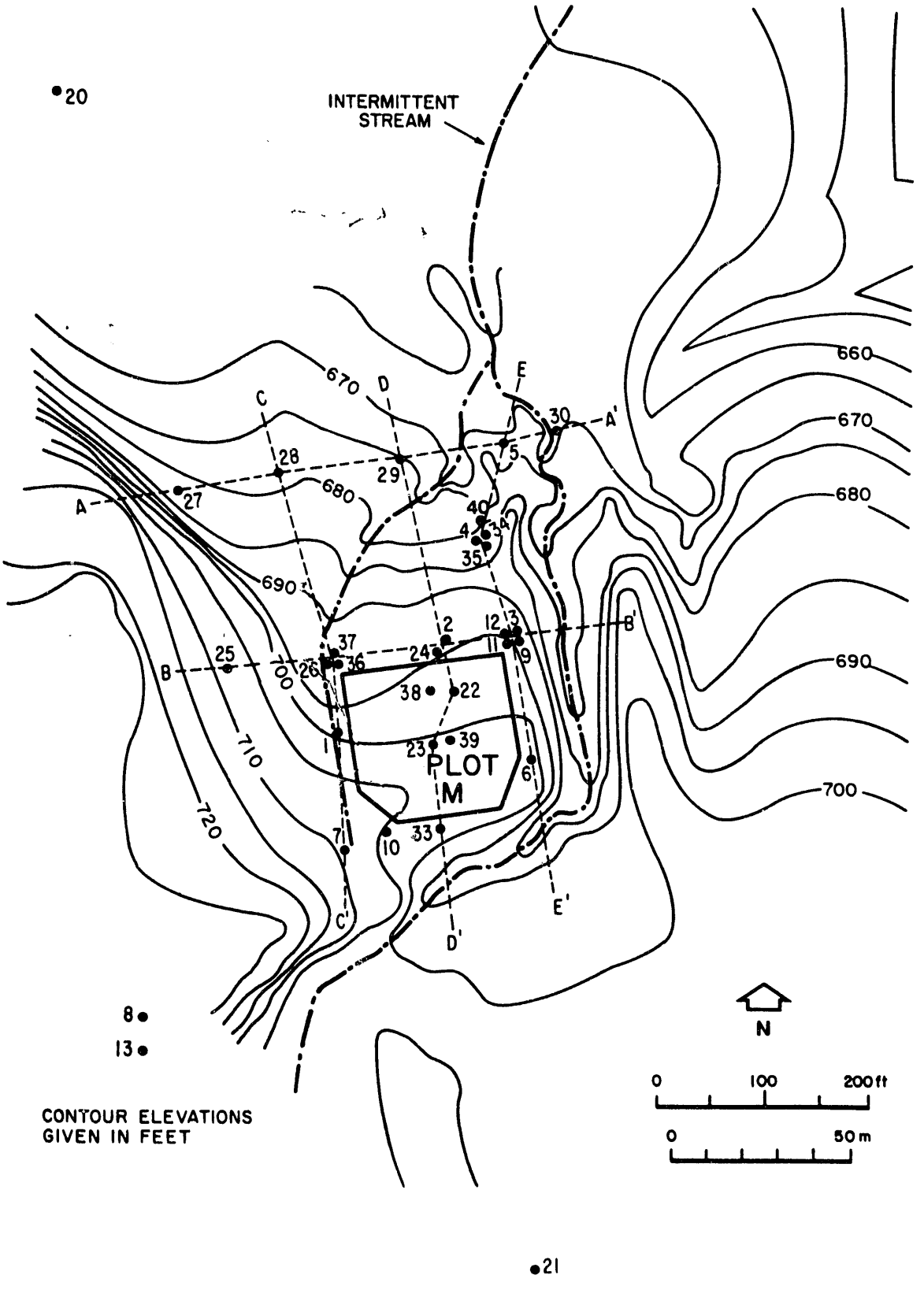

Figure 3.2 Map of Plot M Palos Site Showing Topography, Intermittent Stream, and Borehole Locations

Surface water samples were collected from five surface water bodies in the vicinity of Site A on December 4, 1992. These are: the pond northwest of Site A; the pond southeast of Site A; Horsecollar Slough; Tomahawk Slough; and Bull Frog Lake. Most of these locations can be identified in Figure 1.2. These samples were all analyzed for tritiated water and the concentrations were all less than the detection limit of 0.1 nCi/L. The results indicate that there has been no surface migration of radioactive materials from Site A.

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 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 principal purpose of this arrangement is to obtain water level measurements at different depths to determine the vertical gradient of the hydraulic head.

The tritium concentrations varied widely as 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.

TABLE 3.4

Tritium Content in Borehole Water Samples, 1992

(Concentrations in nCi/L)

Borehole Number	Depth (ft)	Date Collected				
		January 31	March 17	May 20	August 31	December 11
1	40	1580	1611	1719	1706	1540
2	40	202	213	208	528	225
3	40	3105	3149	3126	3006	2907
4	40	1828	1797	1868	1296	1788
5	40	74.5	65.1	52.0	66.9	62.3
6	40	89.5	25.8	122	244	86.3
8	40	0.2	< 0.1	0.5	< 0.1	0.5
9	40*	14910	15300	20310	14280	11120
10	40*	3070	1246	1291	1626	2731
11	39	635	495	996	869	540
11	68	11140	9324	12800	12330	7691
11	124	2.6	0.3	6.4	17.7	6.3
24	126	30.6	0.3	8.1	37.3	37.3
26	60	782	557	794	842	802
28	60	178	163	157	151	168
35	110	193	169	192	237	272
36	127	158	46.0	100	168	125

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

During 1990, 1991, and 1992, the concentration in Borehole #4 remained elevated, but the concentration in Borehole #5 did not consistently increase.

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 that evaluated the Argonne National Laboratory-East environment, safety, and health programs in the fall of 1990 also reviewed the Site A/Plot M monitoring program. The Tiger Team found that the 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. However, the EPA sampling protocol was applied for all sampling during 1992.

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

TABLE 3.5

Water Level Measurements in Boreholes Near Plot M, 1992
(Units of feet below the benchmark at the top of the well)

Borehole Number	Depth (ft)	Date Measured				
		January 31	March 17	May 20	August 31	December 11
1	40	35.33	34.01	29.27	35.63	36.90
2	40	22.83	19.87	20.82	28.71	24.30
3	40	33.08	32.07	29.35	32.36	32.70
4	40	13.35	10.54	9.75	19.14	15.00
5	40	22.35	22.44	20.76	24.41	23.80
6	40	9.44	8.52	11.84	32.02	11.71
8	40	35.42	34.21	32.43	35.83	35.58
11	39	21.68	18.30	19.83	27.94	23.50
11	68	57.07	51.01	41.48	47.30	60.00
11	124	104.58	104.29	104.42	104.46	104.45
24	125	111.34	81.36	81.54	113.19	81.36
26	60	44.06	42.36	40.13	44.29	45.25
28	60	56.39	56.25	54.90	56.46	57.15
35	110	93.54	93.12	93.31	93.37	93.50
36	127	103.86	100.43	103.71	105.80	104.91
40	25	0.94	0.00	2.20	*	*

*Plugged by vandals.

collected in May 20, 1992, and another set was collected December 15, 1992. 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 nine of the 17 sampled boreholes. Borehole #40 was unavailable for sampling this year due to vandalism. 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 Borehole #11 at 68 ft (9.58 pCi/L). The highest concentration found in 1991 was 10.7 pCi/L in Borehole #11 (68'). This borehole water also has the highest tritium 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.

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. Water was collected from the dolomite holes quarterly. 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. Two of the wells, DH 13 and DH 14, were not available for sampling during most of the year. The DH 13 well was vandalized and filled with debris, while DH 14 contained USGS equipment that made the well inaccessible for sampling. Several other dolomite holes were unavailable for sampling due to an inability to access the wells.

The results of the tritiated water analysis of the dolomite holes are consistent with concentrations measured in the past. In all, nine of the dolomite holes had elevated tritiated water concentrations. The highest

TABLE 3.6

Radiochemical Analyses of Borehole Water Samples Near Plot M, 1992
(Concentrations in pCi/L)

Borehole*	Date Collected	Strontium-90
1 (40′)	May 20	< 0.25
	December 15	< 0.25
2 (40′)	May 20	0.32 ± 0.04
	December 15	0.80 ± 0.25
3 (40′)	May 20	0.38 ± 0.03
	December 15	2.97 ± 0.21
4 (40′)	May 20	3.73 ± 0.07
	December 15	0.74 ± 0.13
5 (40′)	May 20	< 0.25
	December 15	< 0.25
6 (40′)	May 20	5.78 ± 0.07
	December 15	4.48 ± 0.18
8 (40′)	May 20	< 0.25
	December 15	0.33 ± 0.26
9 (40′)	May 20	4.96 ± 0.09
	December 15	4.46 ± 0.18
10 (40′)	May 20	< 0.25
	December 15	< 0.25
11 (39′)	May 20	3.38 ± 0.08
	December 15	3.22 ± 0.21
11 (68′)	May 201	9.58 ± 0.10
	December 15	5.43 ± 0.22
11 (124′)	May 20	< 0.25
	December 15	< 0.25
24 (125′)	May 20	< 0.25
	December 15	< 0.25
26 (60′)	May 20	0.51 ± 0.03
	December 15	0.43 ± 0.15
28 (60′)	May 20	< 0.25
	December 15	< 0.25
35 (110′)	May 20	0.36 ± 0.03
	December 15	0.45 ± 0.14
36 (127′)	May 20	< 0.25
	December 15	0.33 ± 0.13

*See Figure 3.1.

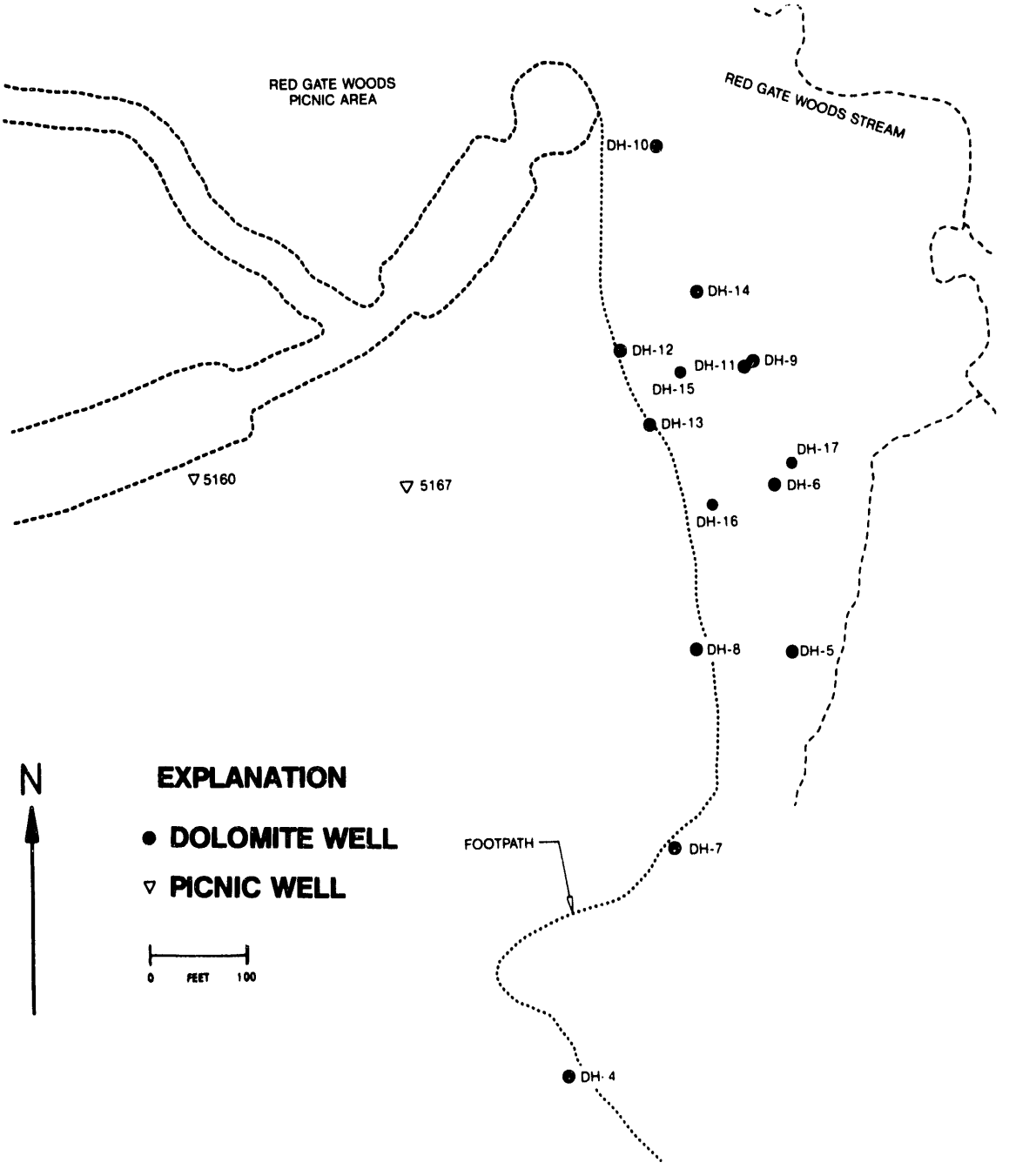

Figure 3.3 Locations of Dolomite Holes North of Plot M

TABLE 3.7

Tritium in Site A/Plot M Dolomite Holes, 1992
(Concentrations in nCi/L)

Dolomite Hole Number	Date Collected			
	February 11	June 19	September 25	December 16
1	< 0.1	< 0.1	< 0.1	< 0.1
2	< 0.1	< 0.1	< 0.1	< 0.1
3	1.6	-	-	< 0.1
4	< 0.1	-	-	-
5	< 0.1	< 0.1	< 0.1	< 0.1
6	1.5	1.4	1.1	1.5
7	< 0.1	< 0.1	< 0.1	< 0.1
8	< 0.1	< 0.1	< 0.1	< 0.1
9	2.7	2.0	1.7	2.1
10	4.4	-	-	2.6
11	3.9	4.0	3.9	1.2
12	5.5	5.4	5.0	1.3
13	-	-	-	-
14	-	-	5.1	2.9
15	2.9	3.1	2.1	0.4
16	< 0.1	< 0.1	< 0.1	< 0.1
17	1.2	1.1	1.1	< 0.1

TABLE 3.8

Water Level Measurements in Dolomite Holes Near Plot M, 1992
(Units of feet below the benchmark at the top of the well)

Dolomite Hole Number	Date Measured			
	February 11	June 19	September 25	December 16
1	-	*	162.05	161.05
2	-	*	140.41	139.62
3	-	*	*	88.15
4	-	*	*	*
5	78.40	78.51	79.11	78.30
6	75.44	75.52	74.37	73.65
7	-	81.56	82.25	81.65
8	-	73.91	74.47	74.05
9	73.28	72.52	73.24	72.90
10	64.95	*	*	64.15
11	76.04	76.10	76.51	75.75
12	76.04	76.10	77.66	76.80
13	76.04	Dry	Dry	Dry
14	76.04	76.10	72.67	72.00
15	79.81	79.90	80.30	79.50
16	76.00	76.08	76.55	75.64
17	75.04	75.12	75.54	74.80

*Unable to open well cap.

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 interpretation[19] 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 dolomite holes have collapsed and water levels in them indicate they are open to glacial drift or till, 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.

A study was conducted to determine if any chemical constituents used or generated at Site A and/or buried at Plot M entered the environment and migrated into the dolomite water. Samples were collected each quarter from DH 1, DH 2, DH 3, and DH 4 (see Figure 1.2). These samples were analyzed for volatile organic compounds. The only quantified constituents identified were acetone and methyl ethyl ketone in DH 1. The results are:

Quarter	Acetone (ppb)	Methyl Ethyl Ketone (ppb)
First	84	14
Second	78	21
Third	77	19
Fourth	< 5	< 5

These results are almost a factor of ten lower than the one sample obtained in 1991 and were below the detection limit by the end of the year. Since the concentrations changed rapidly and no hydrogen-3 was ever observed in this dolomite water, it may imply a recent addition of acetone, accidental or deliberate, to this water. There are no USEPA drinking water limits for either of these compounds.

3.3.3 Well Water

In July 1988, a 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. Sampling from the well at 95th and Archer (#5157) was not conducted during CY 1992 or in the future since this well was plugged by the Palos Forest Preserve. 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

TABLE 3.9

Tritiated Water Content of Wells Near Site A/Plot M, 1992
(Concentrations in nCi/L)

	Red Gate North 5160	Red Gate 5167	Opposite Red Gate 5159	330 yds East Red Gate 5158	Guard Post 5215
January 8	0.54	< 0.1	2.13	0.13	< 0.1
January 22	0.37	< 0.1	1.77	-	-
February 5	0.36	< 0.1	1.34	< 0.1	< 0.1
February 19	0.38	< 0.1	1.59	-	-
March 4	0.32	< 0.1	1.23	< 0.1	< 0.1
March 18	0.31	< 0.1	1.21	-	-
April 1	0.16	< 0.1	1.54	0.11	< 0.1
April 15	0.34	< 0.1	1.84	-	-
May 6	0.23	< 0.1	2.20	0.12	< 0.1
May 20	0.16	< 0.1	2.29	-	-
June 3	0.15	< 0.1	2.22	0.11	< 0.1
June 17	0.19	< 0.1	1.50	-	-
July 1	0.22	< 0.1	1.33	< 0.1	< 0.1
July 15	0.22	< 0.1	1.19	-	-
August 5	0.27	0.13	1.17	< 0.1	< 0.1
August 19	0.34	< 0.1	1.05	-	-
September 2	0.26	< 0.1	0.74	0.14	< 0.1
September 16	0.20	< 0.1	0.20	-	-
October 8	0.15	< 0.1	0.16	< 0.1	< 0.1
October 21	0.16	< 0.1	0.18	-	-
November 4	0.20	< 0.1	0.13	< 0.1	< 0.1
November 18	0.17	< 0.1	0.15	-	-
December 2	0.20	< 0.1	0.17	< 0.1	< 0.1
December 15	0.18	< 0.1	0.34	-	-
Average	0.25	0.04	1.15	< 0.1	< 0.1

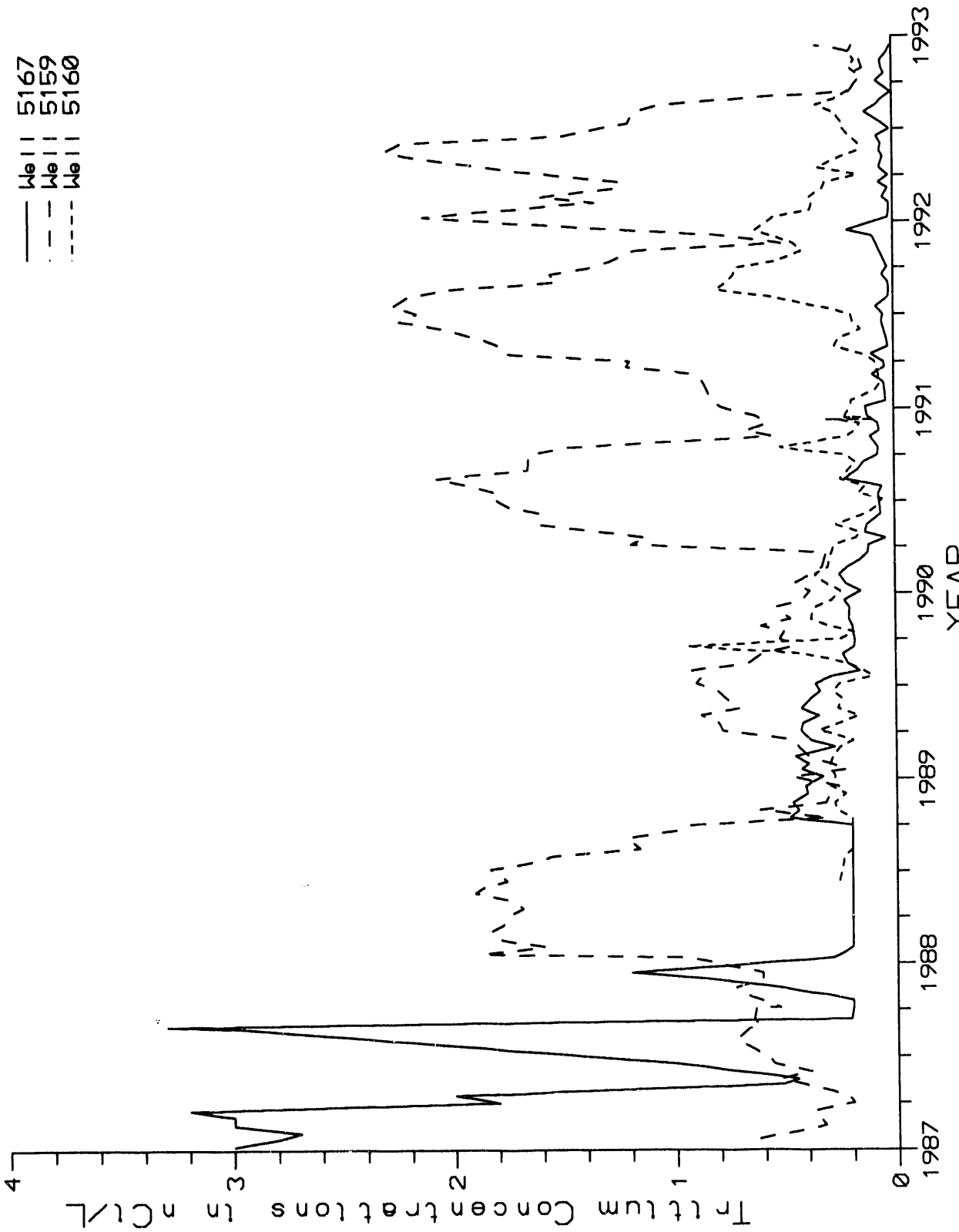

Figure 3.4 Tritiated Water Concentrations in Red Gate Woods (#5167), Opposite Red Gate Woods (#5159), and Red Gate Woods North (#5160) Wells From 1987 Through 1992.

(#5167) dropped from 3.3 nCi/L in 1987 to 0.13 nCi/L in 1992, while the average concentration dropped from 1.6 nCi/L in 1987 to 0.04 nCi/L in 1992. The magnitude of the tritium concentrations in well #5159 may be related to precipitation, with higher concentrations occurring during years of low rain.

The annual average tritium concentrations are slightly higher in the new well (#5160) compared to the old well (#5167), see Table 2.1. It is speculated that the higher concentrations of tritium in the Red Gate Woods North well (#5160) compared to the Red Gate Woods well (#5167) is due to the fact that it is drilled deeper and intercepts lower fractures in the dolomite that are connected to some of the dolomite holes near the intermittent stream, specifically DH 11 through DH 14. The other dolomite holes were not drilled deep enough to intercept this lower fracture. Flow in the dolomite holes is generally downward from the weathered zone to the bottommost fractures. Most of the flow exits the dolomite hole into the major fracture (96-98 feet below the surface), but some bypasses it and flow also occurs at lower fractures (157 feet). This lower fracture is intercepted by well #5160 but not #5167 since this lower fracture (157 feet) was grouted in 1988. The upper fracture (96-98 feet) has been cased off in #5160. Therefore, the tritium present in the lower sections of the deepholes 11 to 14 moves through the lower fracture (157 feet) and is measured in well #5160.

The other wells, although also downgradient from Plot M, are evidently too far from the Plot to show measurable tritium concentrations. Two of the picnic wells, #5159 and #5158, were not available to the public during the year. The Forest Preserve District of Cook County 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 6, 1992, and November 13, 1992, 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 #5148 in Figure 1.2. All the tritium results were less than the detection limit of 0.1 nCi/L.

The Red Gate Woods North well (#5160) is the location which provides the greatest potential radiation exposure to the public in 1992. If water

equal to the Red Gate Woods North well average concentration of 0.25 nCi/L were the sole source of water for an individual, the annual dose from the tritium would be 0.011 mrem. If an individual consumed one liter of this water, the dose would be 2×10^{-5} mrem.

In addition to tritiated water measurements, one set of water samples from the picnic wells were collected on May 6, 1992, and analyzed for isotopic uranium, total alpha, total beta, strontium-90, and the transuranic nuclides. The total alpha (0.1 to 1.5 pCi/L) and total beta (2.6 to 10.0 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 3.10. The range of concentrations is similar to that found previously and are consistent with concentrations of uranium found in well water away from Site A/Plot M.

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 3.11. 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.[20] The constituents in Table 3.11 that do not have a specific limit are provided for completeness. Although the limits are exceeded for sulfate and manganese, this is probably due to natural levels. 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. These concentrations are the highest early in the year, note the lead results, when the pumps have received very little use. 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.

TABLE 3.10

Uranium Content of Well Water Near Plot M, 1992
(Concentrations in pCi/L)

Well Number*	Location	Date Collected			
		February 5	May 6	August 5	November 4
5160	Red Gate Woods North	0.25 ± 0.13	0.11 ± 0.07	0.16 ± 0.06	0.13 ± 0.06
5167	Red Gate Woods	0.16 ± 0.08	0.17 ± 0.08	0.36 ± 0.10	0.10 ± 0.10
5159	Opposite Entrance to Red Gate Woods	1.16 ± 0.22	1.83 ± 0.34	0.97 ± 0.16	1.22 ± 0.19
5158	300 yds NE of Entrance to Red Gate Woods	-	0.20 ± 0.10	-	-
5215	Guard Post	-	0.20 ± 0.09	-	-

*See Figure 1.2

TABLE 3.11

Inorganic Constituents in Red Gate Woods North Well Water (#5160), 1992
(Concentrations in mg/L)

Inorganic Constituent	February	May	August	November	Limit**
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	0.05
Barium	0.026	0.019	0.018	0.035	1.0
Beryllium	< 0.005	< 0.005	< 0.005	< 0.005	-
Cadmium	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.01
Chloride	11.0	12.0	9.0	11.0	250
Chromium	< 0.01	< 0.01	< 0.01	< 0.01	0.05
Cobalt	< 0.015	< 0.015	< 0.015	< 0.015	-
Copper	0.910	0.217	0.041	0.021	-
Fluoride	0.070	0.226	0.190	0.180	-
Iron	34.60	7.66	8.74	25.90	-
Lead	0.068	0.031	0.033	0.014	0.05
Manganese	1.066	0.924	0.557	0.782	0.15
Mercury*	< 0.1	< 0.1	< 0.1	< 0.1	2.0*
Nickel	< 0.02	< 0.02	< 0.02	< 0.02	-
pH	7.1	7.3	7.2	7.0	-
Silver	< 0.01	< 0.01	< 0.01	< 0.01	0.05
Sulfate	590	710	757	766	250
Thallium	< 0.004	< 0.004	< 0.004	< 0.004	-
Vanadium	< 0.05	< 0.05	< 0.05	< 0.05	-
Zinc	2.38	6.01	2.01	2.53	-

*Concentrations in µg/L.

**State of Illinois concentrations of chemical constituents in drinking water.[20] See text.

3.4 Bottom Sediment

Bottom sediment samples were collected from the stream next to Plot M at Location #1 and Location #9 on June 3, 1992, and on December 15, 1992 (see Figure 3.1). Various radiochemical analyses were performed on these samples and the results are found in Table 3.12. 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.[16]

4.0 SUMMARY OF POTENTIAL RADIATION DOSE ESTIMATES

If a hypothetical individual were exposed continuously to tritium at various locations, the dose could be estimated. Assuming a person breathed the air at Location #9, drank water from Location #9 or the seep, or drank water from Well 5160 or 5167, the dose from exposure for all of 1992 at the maximum and annual average concentrations is collected in Table 4.1. The exposure to air, drinking water, and surface water employs the DOE methodology and limits.

A more meaningful estimation is for the occasional visitor to the Plot M area. Assuming a visitor spends one hour at Location #9 or drinks one liter of water from the surface stream or picnic wells, the dose from this exposure is estimated and presented in Table 4.2. The maximum total dose received by an occasional visitor is the combination of the separate pathways, breathing air at Location #9 and drinking water from the Red Gate Woods North Well (5160). This maximum dose would be 0.00003 mrem per visit.

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 4.3. 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. Therefore, the monitoring program results

TABLE 3.12

Radioactivity Content of Streambed Next to Plot M, 1992
(Concentrations in pCi/g)

Radionuclide	Date Colelcted	Location #1* (Upstream)	Location #9* (Downstream)	Ambient Concentrations[16]
Potassium-40	June 3	21.54 ± 0.68	18.73 ± 0.72	13.9
	December 15	20.64 ± 0.67	19.84 ± 0.65	
Strontium-90	June 3	0.13 ± 0.01	0.13 ± 0.01	-
	December 15	0.10 ± 0.01	0.10 ± 0.01	
Cesium-137	June 3	0.24 ± 0.03	0.47 ± 0.03	0.19
	December 15	0.23 ± 0.02	0.16 ± 0.02	
Radium-226	June 3	2.89 ± 0.09	1.88 ± 0.09	1.25
	December 15	2.60 ± 0.08	1.80 ± 0.07	
Thorium-228	June 3	1.29 ± 0.04	1.04 ± 0.05	0.81
	December 15	1.15 ± 0.04	1.03 ± 0.04	
Thorium-232	June 3	1.00 ± 0.10	0.83 ± 0.10	0.74
	December 15	0.92 ± 0.10	0.88 ± 0.09	
Uranium-234	June 3	1.26 ± 0.10	1.28 ± 0.10	-
	December 15	1.29 ± 0.09	1.04 ± 0.08	
Uranium-238	June 3	1.40 ± 0.11	1.37 ± 0.11	-
	December 15	1.46 ± 0.10	1.13 ± 0.08	
Plutonium-238	June 3	< 0.0001	0.0008 ± 0.0006	0.0005
	December 15	0.0011 ± 0.0006	0.0007 ± 0.0005	
Plutonium-239	June 3	0.0091 ± 0.0017	0.0370 ± 0.0037	0.0059
	December 15	0.0082 ± 0.0017	0.0200 ± 0.0024	
Americium-241	June 3	0.0026 ± 0.0008	0.0041 ± 0.0010	0.0044
	December 15	0.0022 ± 0.0008	0.0021 ± 0.0005	

*See Figure 3.1

TABLE 4.1

Dose From Continuous Exposure to Tritium at Selected Locations, 1992

Pathway	Maximum Conc.	Maximum Dose	Annual Avg. Conc.	Annual Avg. Dose
Air	14.3 pCi/m^3	0.008 mrem/y	5.4 pCi/m^3	0.003 mrem/y
Surface Water				
Seep	1095 nCi/L	50 mrem/y	516 nCi/L	24 mrem/y
Location #9	91.3 nCi/L	4.2 mrem/y	71.3 nCi/L	3.3 mrem/y
Well Water				
Red Gate Woods (5160)	0.54 nCi/L	0.025 mrem/y	0.25 nCi/L	0.011 mrem/y
Red Gate Woods (5167)	0.13 nCi/L	0.006 mrem/y	0.04 nCi/L	0.002 mrem/y

TABLE 4.2

Estimates of Exposures to a Casual Visitor to Plot M, 1992

Pathway	Quantity	Maximum Dose	Annual Average
Air	One Hour	0.0000009 mrem	0.0000003 mrem
Surface Water			
Seep	One Liter	0.068 mrem	0.033 mrem
Location #9	One Liter	0.006 mrem	0.004 mrem
Well Water			
Red Gate Woods (5160)	One Liter	0.00003 mrem	0.00002 mrem
Red Gate Woods (5167)	One Liter	0.00001 mrem	0.000003 mrem

have established that radioactivity at Plot M is very low and does not endanger the health or safety of those living in the area or visiting the site.

TABLE 4.3

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.[21]

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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.[16]

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 and filtered to reduce leaching from suspended solids.

6.2 Applicable Standards

The standard that is relevant to this study is the DOE Order 5400.5 which established a dose limit of 100 mrem/y.[13] The dose limit and dose calculation methodology is applicable to all media: air, surface water, deep holes, boreholes, and drinking water. The EPA drinking water standard[14] 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 tritium may be useful for some comparison purposes.

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.[16]

6.4 Acknowledgements

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