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SITE SURVEILLANCE AND MAINTENANCE PROGRAM FOR PALOS PARK

Report for 1988

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SITE SURVEILLANCE AND MAINTENANCE PROGRAM FOR PALOS PARK

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Abstract

The results of the environmental monitoring program conducted at Site A/Plot M in the Palos Park Forest Preserve area for CY 1988 are presented. The monitoring program is the ongoing remedial action that resulted from the original radiological characterization of the site. That study had determined that hydrogen-3 (as tritiated water) migrated from the burial ground and was 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 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 well continued to show the same pattern of elevated levels in the winter and low concentrations in the summer, but the magnitude of the current winter peak was significantly less than in earlier years. A replacement well was installed in July 1983 in the Red Gate Woods area to provide a source of water for public use that is free of tritium. 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. Recent measurements indicate the presence of strontium-90 and technetium-99 in borehole water next to Plot M. The available data do not allow a firm conclusion as to whether the presence of these nuclides represent recent migration or rather movement that may have occurred before the Plot was capped. The results of the program established 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

This report presents and discusses the monitoring data obtained during CY 1988. The program is the ongoing remedial action that resulted from the 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] and 1986,[7] and 1987[8]. Earlier data will not be repeated in this progress 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 containment shell and biological shield for the CP-2 and CP-3 reactors, together with various pipes, valves, and 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, 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 concrete slab was poured

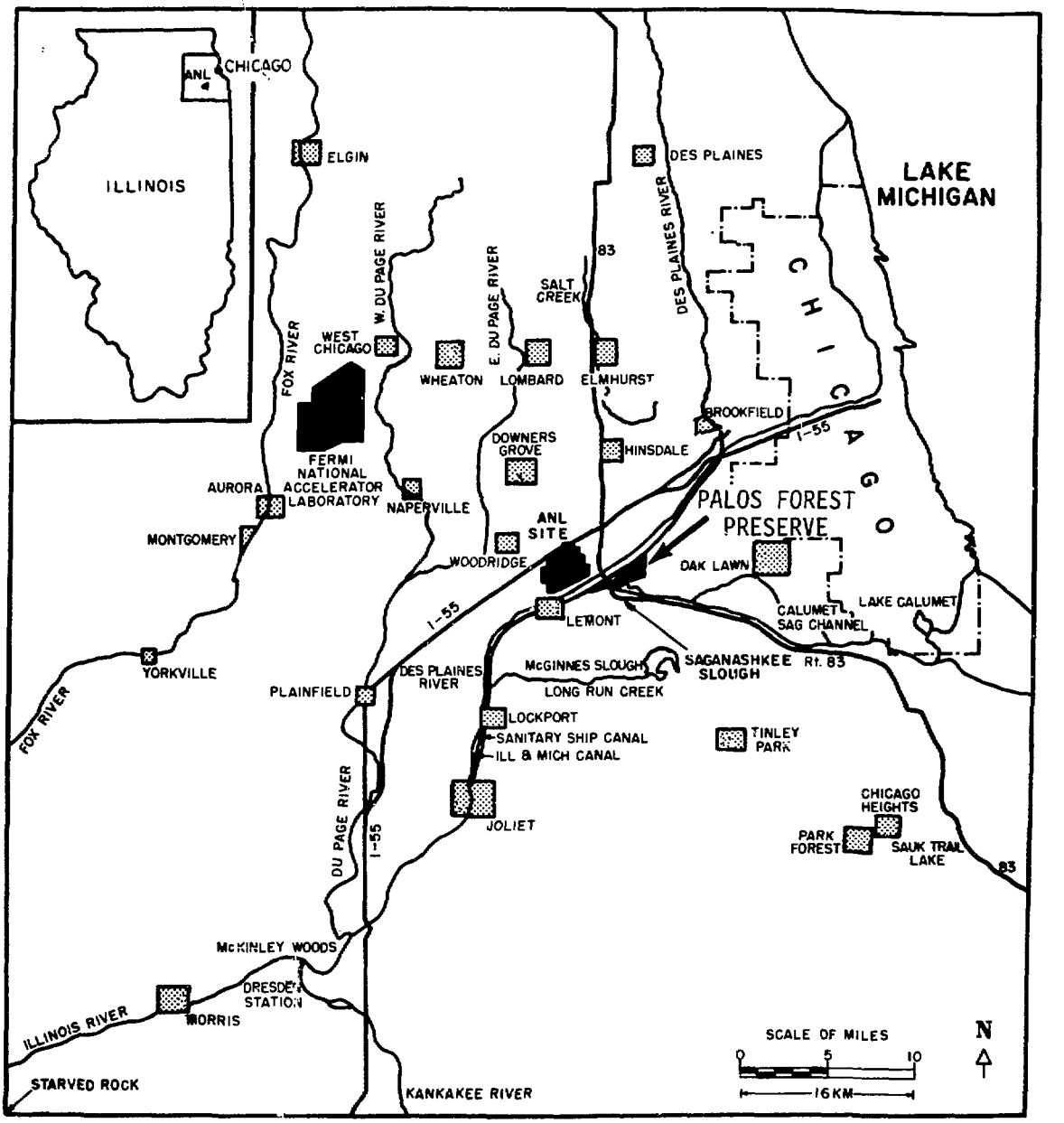

Figure 1.1 Location of Palos Forest Preserve on Chicago-Area Map

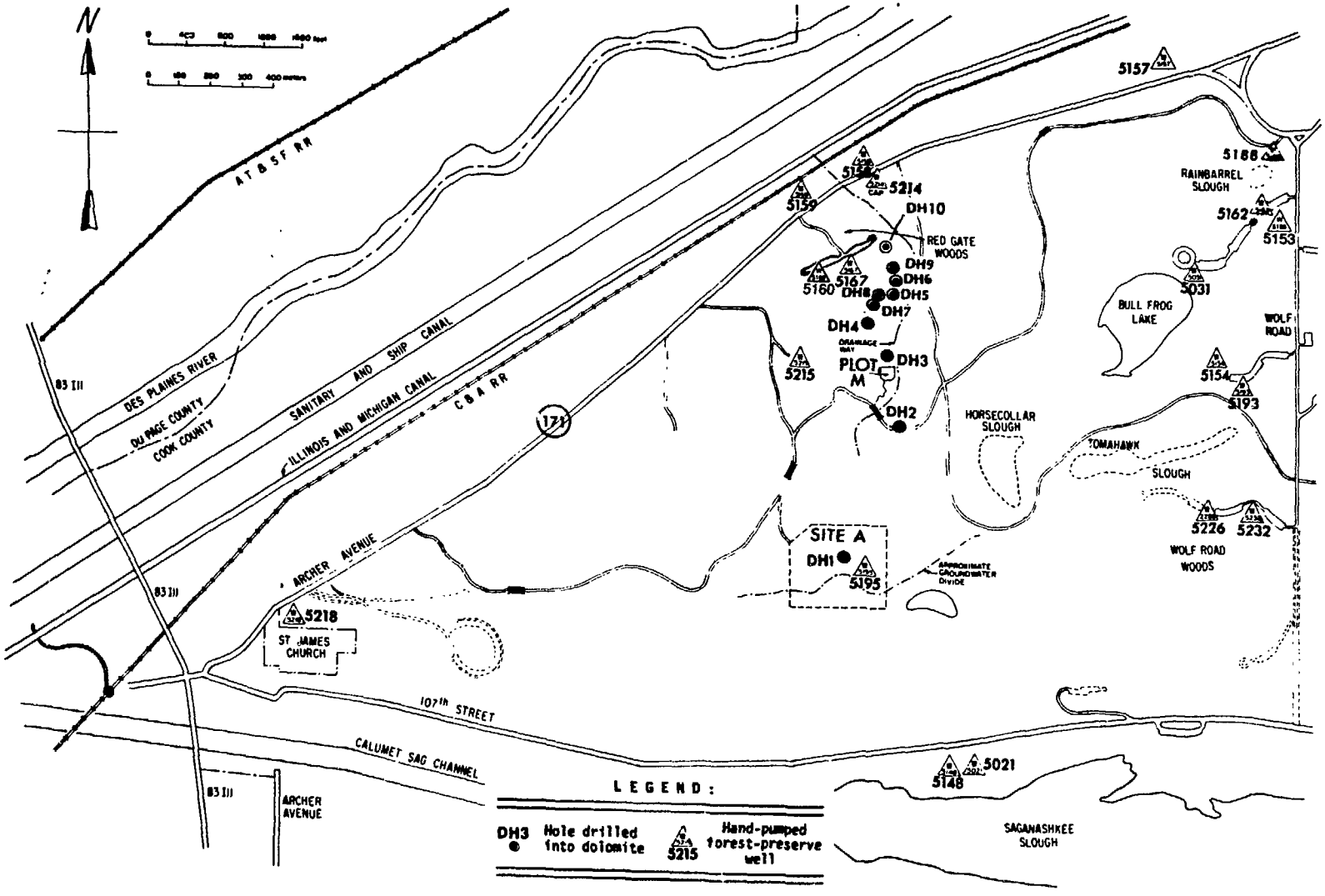

Figure 1.2 Palos Forest Preserve Showing Location of Site A/Plot M Dolomite Holes and Picnic Wells

over the top. The concrete slab was covered with soil and seeded with grass.

In 1973, elevated levels of hydrogen-3 (as water) were detected in two nearby hand-pumped picnic wells and found to be migrating from the burial plot into the surrounding soil and aquifers. As a result, an extensive radiological survey of the entire Palos Park site was conducted.

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 Calummet 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 sedimentary rocks. The uppermost bedrock is Silurian dolomite, into which both the picnic wells and some of the monitoring wells are placed and sampled, 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 and Calumet Sag Channel, 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 swamps, ponds, and intermittent streams. 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, when there is sufficient water, into the Illinois and Michigan Canal. The ground water 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 Channel to the south. Water usage at the site 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.

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. These were in existence before this radiological and hydrological study of the area was begun, except for well #5160.

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 (pCi/g) of the oven-dried (110°C) weight for soil and sediment samples. Radiation dose calculations are reported in units of millirem (mrem) or millirem per year (mrem/y). Other abbreviation of units are defined in the text.

2.0 Summary

The results of the ongoing environmental monitoring and surveillance program at the Palos Park site for CY 1988 are presented in this report. Sample collection and analyses were conducted on air, surface and subsurface water, and bottom sediment. Water vapor samples were collected over the streambed at two locations which were upstream and downstream of the waste burial Plot 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 possible 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 0.007 mrem/y, or 0.007% of the applicable U. S. Department of Energy (DOE) Radiation Protection Standard of 100 mrem/y.

Surface water samples collected from the stream that flows around Plot M showed the same tritiated water concentration pattern as was observed in the past. Concentrations were at the ambient level (< 0.2 nCi/L) upstream of the Plot, increased to 25-190 nCi/L adjacent to the Plot, then decreased to 10-20 nCi/L further downstream. Other radiochemical analyses of water and stream-bed sediment collected above and below Plot M indicated that there are slightly higher concentrations of strontium-90 (in water only), uranium (in water only), and plutonium-239 (in sediment only) downstream. For both the water and sediment samples, the concentrations were very low compared to ambient or fallout levels.

The tritiated water concentrations in the borehole and dolomite hole water were consistent with those observed in the past. Water from ten of 17 boreholes analyzed for strontium-90 contained concentrations greater than the detection limit of 0.25 pCi/L, which is considered the normal or ambient level. Technetium-99 was identified above the detection limit of 0.5 pCi/L in eight of the 17 boreholes analyzed. The elevated strontium-90 levels found in some boreholes are probably from the Plot, since concentrations above 0.25 pCi/L have not been observed in the water from atmospheric fallout from previous nuclear weapons testing, and no other source is known. Both strontium-90 and technetium-99 are relatively mobile species and their presence in the borehole water is not unexpected and probably due to movement that occurred before the Plot was capped.

Sampling of the Forest Preserve picnic wells continued. Although the pattern of high tritium concentrations in the winter and low concentrations (less than the detection limit of 0.2 nCi/L) in the summer continued, the magnitude of the winter peak (0.5 nCi/L) and the annual average (0.2 nCi/L) in the Red Gate Woods well are significantly less than in earlier years. The corresponding values for the maximum and average concentrations are

presented in Table 2.1. Tritium concentrations were measured in the new well at Red Gate Woods during the second half of 1988 and were all at or slightly above the detection limit of 0.2 nCi/L. The maximum tritium concentration in the well opposite Red Gate Woods doubled compared to past years with maximum and minimum concentrations of 1.9 nCi/L and less than 0.2 nCi/L, respectively. The other wells were only occasionally greater than 0.2 nCi/L. A severe drought that occurred during late spring and all summer may have hade an effect on some tritium concentrations. If water equal to the Red Gate Woods well average concentration of 0.2 nCi/L were the sole source of water for an individual, the annual dose from tritium would be 0.009 mrem. Compared to the U. S. Environmental Protection Agency (EPA) drinking water limit of 20 nCi/L,[9] this concentration is 1% of the annual limit. Consumption of one liter of this water would produce a dose of 1.3×10^{-5} mrem.

The results of this program show that the radioactivity remaining at Palos Park 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.

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 1988, 294 samples were collected and 362 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 standard[9] or the U. S. Department of Energy Radiation Protection Standard of 100 mrem/y.[10] The

TABLE 2.1

Annual Maximum and Average Hydrogen-3 Concentrations in the Red Gate Woods Well (#5167)

(Concentrations in nCi/L)

Year	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	0.5	0.2

Site A/Plot M program follows the guidance for monitoring at DOE facilities.[11]

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.)
0.2-1.0	25-5%
1-10	5-1%
> 10	1%

3.1 Air

Water vapor samples were collected over the surface streambed 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 tritium-in-air concentrations.[12]

During some of the sampling periods, water was not flowing in the stream, but 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 substantially lower than the spring values and are due to generally higher tritium stream concentrations in the spring. The dose to a hypothetical individual who breathed air continuously for one year at the maximum concentration of 13.7 pCi/m^3 would be 0.007 mrem or 0.007% of the applicable DOE environmental dose limit of 100 mrem/y. This dose was calculated using the methodology specified in the DOE Draft Order[10] for determining radiation exposures to members of the public in uncontrolled areas. The total quantity of radionuclide inhaled, in microcuries (μCi), is obtained by multiplying the air concentration by the general public

TABLE 3.1

Concentrations of Tritiated Water Vapor Above the Streambed Adjacent to Plot M, 1988

(Concentrations in pCi/m^3)

Sampling Period	Location #1* (Upstream)	Location #9* (Downstream)
April 5 to April 8	0.8 ± 0.8	4.4 ± 0.6
April 11 to April 14	0.2 ± 0.6	4.7 ± 0.7
April 18 to April 21	-	3.1 ± 0.3
April 25 to April 28	0.4 ± 0.5	3.5 ± 0.5
May 2 to May 5	1.5 ± 0.5	13.7 ± 0.8
Spring Average	0.7 ± 0.6	5.9 ± 4.0
October 4 to October 7	0.3 ± 0.4	2.7 ± 0.5
October 11 to October 14	0.1 ± 0.4	1.1 ± 0.4
October 17 to October 20	0.4 ± 0.6	0.6 ± 0.6
October 24 to October 27	0.1 ± 0.3	0.3 ± 0.3
October 31 to November 3	1.0 ± 0.4	0.7 ± 0.4
Fall Average	0.4 ± 0.3	1.1 ± 0.8

*See Figure 3.1.

breathing rate of 8400 m^3/y.[13] This annual intake is then multiplied by the 50-year Effective Dose Equivalent Factor (EFF.D.E.) to obtain the dose. The EFF.D.E. for tritiated water vapor is 6.3×10^{-5} rem/μCi (rem per microcurie).

3.2 Surface Water

Only two sets of samples were collected from the stream that flows around Plot M because of the extended drought during the summer. 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. The concentrations in the stream declined by a factor of two to three compared to recent years.

Using the methodology prescribed in the DOE guidance,[10] the committed dose equivalent for consumption of water can be calculated. 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 1988 concentration of 189 nCi/L would be about 8.7 mrem/y and a dose of 6.0 mrem/y based on the annual average seep concentration of 130 nCi/L. Using the same calculations for concentrations at Location #9, the maximum concentration of 34.1 nCi/L would produce 1.6 mrem/y and the 1988 average concentration of 25.9 nCi/L would give a dose of 1.2 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 November 28, 1988, 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 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

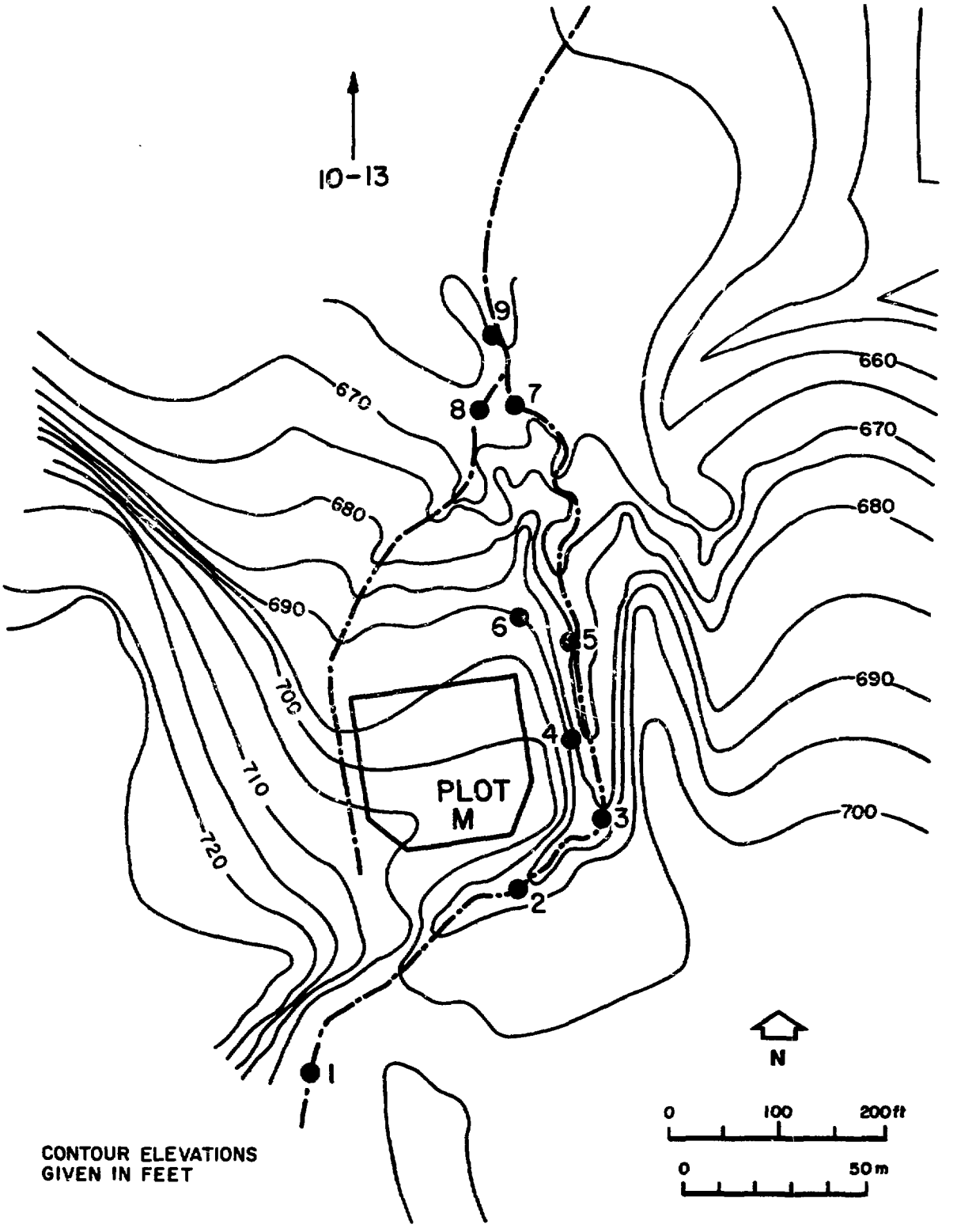

Figure 3.1 Surface Water Sampling Locations Near Plot M

TABLE 3.2

Tritiated Water Content of Stream
Next to Plot M, 1988

(Concentrations in nCi/L)

Location Number*	Date Collected	
	January 19	November 28
1	< 0.2	< 0.2
2	0.5 ± 0.1	0.6 ± 0.1
3	43.5 ± 0.4	33.3 ± 0.4
4	26.2 ± 0.3	31.4 ± 0.4
5	25.8 ± 0.3	25.4 ± 0.3
6 (Seep)	188.9 ± 0.9	70.6 ± 0.5
7	34.0 ± 0.4	20.8 ± 0.3
8	27.4 ± 0.3	6.9 ± 0.2
9	34.1 ± 0.4	17.7 ± 0.3
10	29.3 ± 0.4	13.8 ± 0.3
11	20.2 ± 0.3	12.3 ± 0.2

*See Figure 3.1.

TABLE 3.3

Radioactivity Content of Stream Next to Plot M, 1988
Samples Collected November 28, 1988

(Concentrations in pCi/L)

Constituent	Location #1* (Upstream)	Location #9* (Downstream)
Total Alpha**	0.4 ± 0.1	1.0 ± 0.2
Total Beta**	5.7 ± 0.3	7.4 ± 0.3
Hydrogen-3	< 200	1.77×10^4 ± 285
Strontium-90	0.6 ± 0.1	1.0 ± 0.2
Uranium-234	0.15 ± 0.03	0.48 ± 0.10
Uranium-235	< 0.01	< 0.01
Uranium-238	0.06 ± 0.04	0.45 ± 0.10
Neptunium-237	< 0.001	< 0.001
Plutonium-238	< 0.001	< 0.001
Plutonium-239	< 0.001	< 0.001
Americium-241	< 0.001	< 0.001
Curium-242 and/or Californium-252	< 0.001	< 0.001
Curium-244 and/or Californium-249	< 0.001	< 0.001

*See Figure 3.1.

**Non-volatile.

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 these radionuclides. No spring samples were collected because of a lack of surface flow during the spring and summer as a result of the drought.

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 till. Water samples were collected and water level measurements were made in these boreholes approximately bimonthly, weather permitting. 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 piezometer at 68 feet was dry all 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 by the DOE Environmental Survey late in 1987 and added to the 1988 sampling schedule.

The tritium concentrations varied more widely than in past years. Several boreholes (#2, #6, #26, and #36) north of Plot M showed a general increase in tritium concentration this year, but may be caused by the lack of dilution due to the drought. However, the average concentrations of the other boreholes were similar to those observed in past years.

In the 40-foot deep boreholes, low tritium concentrations correlate with high water levels, apparently a dilution phenomenon. The measured water

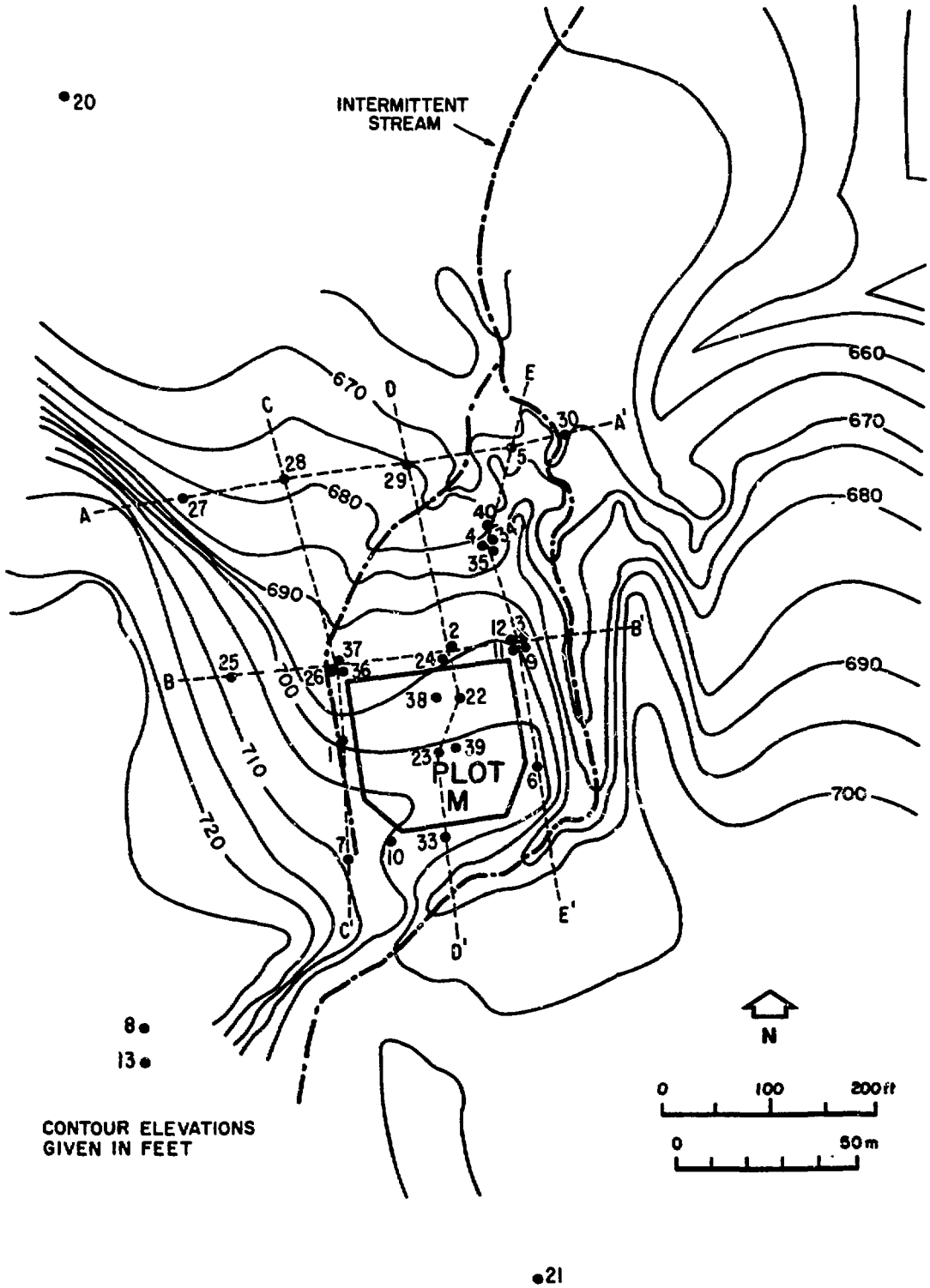

Figure 3.2 Map of Plot M Palos Site Showing Topography, Intermittent Stream, and Borehole Locations

TABLE 3.4

Tritium in Borehole Water, 1988
(Concentrations in nCi/L)

Borehole Number	Depth (ft)	Date Collected			
		January 29	June 13	October 6	November 8
1	40	1091	1416	1429	1460
2	40	351	479	849	4680
3	40	4105	3860	4024	4178
4	40	460	509	466	469
5	40	111	110	114	114
6	40	15.7	122	258	286
8	40	< 0.2	< 0.2	< 0.2	< 0.2
9	40*	1900	954	1.69×10^4	9190
10	40*	2778	9675	Dry	Dry
11	39	1449	1783	2056	2138
11	124	22.7	17.2	38.3	73.5
24	126	114	79.5	104	125
26	60	122	442	707	998
28	60	268	320	276	258
35	110	1074	887	659	628
36	127	426	925	992	1044
40	25	614	487	657	1050

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

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.

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 June 13, 1988, and the fall set was collected on October 6, 1988. Samples were collected from all boreholes that yielded sufficient water for analysis. All samples were analyzed for strontium-90 and technetium-99. The results are shown in Table 3.6. Strontium-90 concentrations greater than the detection limit of 0.25 pCi/L were found in ten of the 17 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. 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. As seen in Table 3.3, measurable strontium-90 concentrations were also found in the stream water below the Plot.

Selected samples of borehole water were analyzed for technetium-99. Technetium is known to form very mobile anionic species that are poorly retarded by the soils. Technetium-99 concentrations greater than the detection limit of 0.5 pCi/L were found in nine of the 17 boreholes analyzed. Concentrations are all very low and a small fraction of the most restrictive limit; the USEPA drinking water limit of 3000 pCi/L.[9] In general, the technetium-99 results do not correlate well with the strontium-90 concentrations. This may imply disposal at different locations within Plot M. The positive technetium-99 concentrations are north of Plot M, which is in the normal subsurface water flow direction. It is not known if any technetium-99 had been buried at Plot M, but fission product mixtures were used at the site and some were probably buried.

TABLE 3.5

Water Level Measurements in Boreholes Near Plot M, 1988
(Units of feet below the benchmark at the top of the well)

Borehole Number	Depth (ft)	Date Measured			
		January 29	June 13	October 6	November 8
1	40	37.10	32.90	38.52	39.30
2	40	21.86	25.72	33.03	33.97
3	40	32.96	28.91	34.72	37.49
4	40	12.75	15.43	23.74	24.98
5	40	20.76	20.78	29.20	32.15
6	40	11.02	26.15	37.85	34.90
8	40	35.35	35.51	36.03	36.54
11	39	21.30	25.33	32.81	34.28
11	68	Dry	Dry	Dry	Dry
11	124	104.23	104.06	104.95	104.47
24	125	93.25	81.82	88.14	93.82
26	60	44.76	42.65	49.14	50.47
28	60	51.88	44.92	49.49	54.67
35	110	93.27	93.03	93.96	93.55
36	127	103.40	103.86	105.11	104.88
40	25	0.98	5.54	11.31	12.82

TABLE 3.6

Radiochemical Analyses of Borehole Water Samples Near Plot M, 1988
(Concentrations in pCi/L)

Borehole	Date Collected	Strontium-90	Technetium-99
1 (40′)	June 14	< 0.25	< 0.5
	October 7	0.4 ± 0.2	-
2 (40′)	June 14	0.5 ± 0.2	-
	October 7	0.5 ± 0.1	< 0.5
3 (40′)	June 13	< 0.25	2.8 ± 0.2
	October 6	< 0.25	< 0.5
4 (40′)	June 13	< 0.25	1.9 ± 0.2
	October 6	< 0.25	< 0.5
5 (40′)	June 13	< 0.25	0.6 ± 0.1
	October 6	< 0.25	4.3 ± 0.2
6 (40′)	June 13	4.9 ± 0.3	1.0 ± 0.1
	October 6	6.1 ± 0.3	0.6 ± 0.2
8 (40′)	June 13	< 0.25	1.0 ± 0.1
	October 6	< 0.25	< 0.5
9(40′)	June 13	13.6 ± 0.9	< 0.5
	October 6	21.2 ± 0.5	-
10 (40′)	June 13	< 0.25	< 0.5
	October 6	Dry	Dry
11 (39′)	June 13	2.4 ± 0.3	2.4 ± 0.1
	October 6	3.2 ± 0.6	1.2 ± 0.1
11 (124′)	June 13	0.3 ± 0.2	< 0.5
	October 6	0.4 ± 0.1	< 0.5
24 (125′)	June 14	0.4 ± 0.7	< 0.5
	October 6	< 0.25	1.3 ± 0.2
26 (60′)	June 14	0.8 ± 0.3	< 0.5
	October 6	0.6 ± 0.2	1.0 ± 0.2
28 (60′)	June 14	< 0.25	< 0.5
	October 6	< 0.25	< 0.5
35 (110′)	June 13	0.5 ± 0.4	0.8 ± 0.1
	October 6	1.4 ± 0.2	0.5 ± 0.1
36 (127′)	June 14	< 0.25	< 0.5
	October 6	< 0.25	< 0.5
40 (25′)	June 13	3.6 ± 0.4	< 0.5
	October 6	3.7 ± 0.7	< 0.5

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 well (#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 is consistent with the USGS interpretation that a large tritium plume underlies the stream. Loss of water through the stream bottom has forced the tritium plume downward and outward resulting in the current configuration of the plume in the dolomite.

DH 9 and DH 11 are located about ten feet apart, but have significantly different tritiated water concentrations. When the USGS drilled DH 11, they collected soil cores down to the dolomite and as a result found that DH 9 is not open to the dolomite. Tritium concentrations in DH 11 cores from the same depth as the bottom of DH 9 were between 20 and 30 nCi/L, which is similar to those in DH 9. Several of the USGS holes had collapsed similar to DH 9, 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

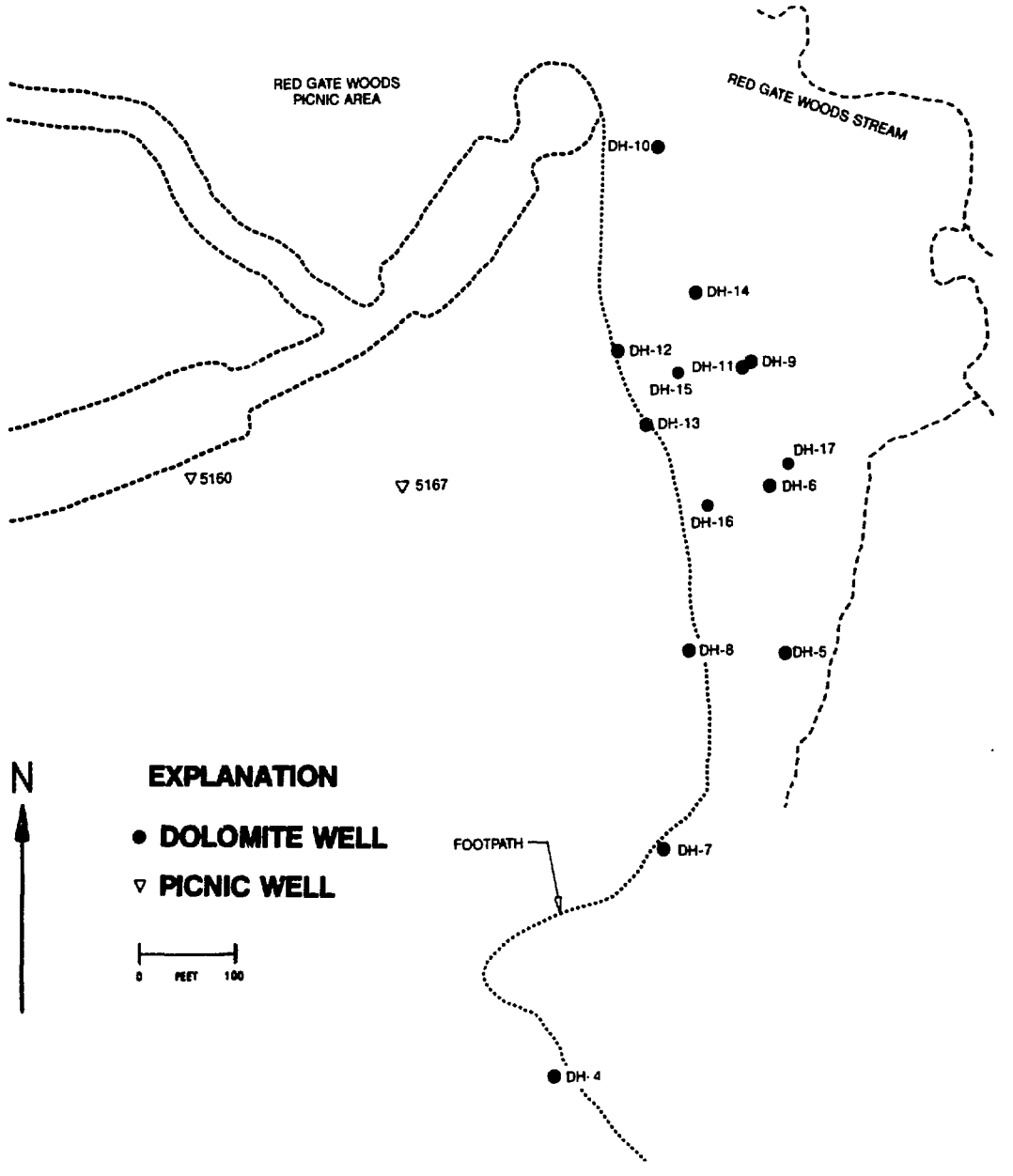

Figure 3.3 Locations of Dolomite Holes North of Plot M

TABLE 3.7

Tritium in Site A Dolomite Wells, 1988
(Concentrations in nCi/L)

Dolomite Hole Number	Date Collected					
	January 20	February 18	June 14	August 29	October 4	November 7
1	-	< 0.2	< 0.2	< 0.2	-	< 0.2
2	-	< 0.2	< 0.2	< 0.2	-	< 0.2
3	-	1.8	1.6	1.8	-	1.8
4	-	< 0.2	< 0.2	< 0.2	-	< 0.2
5	-	< 0.2	< 0.2	< 0.2	-	< 0.2
6	2.8	-	0.8	1.6	1.7	2.0
7	-	< 0.2	< 0.2	< 0.2	-	< 0.2
8	-	< 0.2	< 0.2	< 0.2	-	< 0.2
9	21.3	-	19.7	-	11.8	11.3
10	7.3	-	6.8	6.6	6.8	6.6
11	9.0	-	5.4	8.6	7.8	7.7
12	9.6	-	6.7	6.1	6.5	-
13	5.2	-	4.9	4.8	5.1	5.0
14	9.2	-	6.4	8.9	8.9	11.6
15	3.3	-	2.7	5.0	4.9	5.0
16	< 0.2	-	< 0.2	< 0.2	< 0.2	< 0.2
17	1.4	-	0.4	1.5	1.5	1.7

TABLE 3.8

Water Level Measurements in Dolomite Holes Near Plot M, 1988
(Units of feet below the benchmark at the top of the well)

Dolomite Hole Number	Date Measured					
	January 20	February 18	June 14	August 29	October 4	November 7
1	-	160.06	160.70	161.69	-	161.88
2	-	138.32	139.06	140.09	-	140.25
3	-	96.84	97.65	98.73	-	98.85
4	-	92.02	93.10	93.84	-	94.00
5	-	77.75	77.80	78.74	-	78.90
6	74.16	-	74.74	75.94	76.16	75.95
7	-	81.18	81.55	82.31	-	82.51
8	-	73.76	73.77	74.32	-	74.58
9	72.67	-	72.56	73.44	74.19	73.77
10	63.49	-	64.53	65.34	65.71	65.79
11	74.63	-	75.70	76.52	76.79	76.56
15	78.43	-	79.47	80.32	80.59	80.37
16	74.57	-	75.42	76.50	76.73	76.54
17	73.63	-	74.66	75.55	75.78	75.57

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. Large volume water samples were collected from DH 3 and DH 10 on August 26, 1988, so that additional analyses could be performed. In addition to tritium, the samples were analyzed for total alpha, total beta, strontium-90, isotopic uranium, and the transuranic nuclides. The total alpha, total beta, and isotopic uranium results 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. This indicates that only tritium has migrated to the dolomite near DH 3.

3.3.3 Well Water

In July 1988, a new well was installed in the Red Gate Woods picnic area (#5160) to replace the existing well (#5167) as a water supply for visitors to this area. This will be referred to as the Red Gate Woods North well (#5160). This well was cased 20 feet into the dolomite zone to seal off those fractures that contained the tritiated water. Previous packer experiments had indicated that the tritium moved at the till-dolomite interface and in the uppermost fractures in the dolomite zone. By extending the casing 20 feet into the dolomite and cementing the void between the casing and dolomite, these fractures would not provide tritium to the new well. In addition, the new well would eliminate the elevated lead concentrations found occasionally in the old well. At the same time, the pump mechanism was removed from the Red Gate Woods well to prevent its use by the public, but 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 rock zone as the previously discussed dolomite holes. All the samples were analyzed for tritiated water and the results are listed in Table 3.9. Concentrations of tritium in the new Red Gate Woods North well (#5160) were at or slightly above the detection limit of 0.2 nCi/L during the second half of 1988 when the well was available to the public. Monitoring of this well for at least a full year will be required to determine the long-term tritium trends and to allow for complete development of the well.

The Red Gate Woods well (#5167) continues to reach a maximum in the fall and winter and a minimum in the summer, while the well opposite Red Gate Woods (#5159) shows a maximum in the spring and a minimum in the fall. However, the magnitude of the winter peak in the Red Gate Woods well (#5167) is significantly less than in earlier years and has been trending downward over the last few years. This is illustrated in Figure 3.4 which shows a plot of the individual results for the past six years. The maximum tritium concentration in the Red Gate Woods well (#5167) dropped from 3.3 nCi/L in 1987 to 0.5 nCi/L in 1988 and the annual average concentration dropped from 1.6 nCi/L in 1987 to 0.2 nCi/L in 1988. However, the maximum tritium concentration in the well opposite Red Gate Woods (#5159) increased from 0.7 nCi/L in 1987 to 1.9 nCi/L in 1988 and the annual average concentration increased from 0.54 nCi/L in 1987 to 1.32 nCi/L in 1988. These changes may be related to the extended drought during the spring and summer but more data will be needed to determine the effect. Precipitation infiltration of the Plot M stream near Red Gate Woods creates a groundwater mound which transports water to the Red Gate Woods well. Because of the lack of precipitation very little of this type of transport occurred. The tritium concentrations in the well opposite Red Gate Woods were higher since this well is close to the subsurface sand lense and dilution by precipitation was minimal.

The other wells, although also downgradient from Plot M, are evidently too far from the Plot to show consistently elevated tritium concentrations, although occasional results are above the detection limit. Three of the picnic wells, #5159, #5157, and #5158 were not available to the public during the year because the Cook County Forest Preserve District removed the

TABLE 3.9

Tritiated Water Content of Wells Near Site A/Plot M, 1988
(Concentrations in nCi/L)

Date Collected	5160 Red Gate North (New)	5167 Red Gate	5159 Opposite Red Gate	5158 300 yds. East Red Gate	5157 95th & Archer
January 12	-	0.29	0.94	< 0.2	< 0.2
January 20	-	0.25	1.88	-	-
February 3	-	< 0.2	1.59	< 0.2	< 0.2
February 17	-	< 0.2	1.80	-	-
March 2	-	< 0.2	1.84	< 0.2	< 0.2
March 16	-	< 0.2	1.78	-	-
April 6	-	< 0.2	1.75	< 0.2	< 0.2
April 20	-	< 0.2	1.69	-	-
May 4	-	< 0.2	1.73	< 0.2	< 0.2
May 18	-	< 0.2	1.91	-	-
June 1	-	< 0.2	1.87	< 0.2	< 0.2
June 15	0.26	< 0.2	1.76	-	-
July 6	-	-	1.84	< 0.2	< 0.2
July 20	0.24	-	1.63	-	-
August 3	0.24	< 0.2	1.56	< 0.2	< 0.2
August 17	< 0.2	< 0.2	1.16	-	-
September 7	< 0.2	< 0.2	1.22	< 0.2	< 0.2
September 21	< 0.2	< 0.2	0.98	-	-
October 5	< 0.2	< 0.2	0.93	< 0.2	< 0.2
October 19	< 0.2	0.48	0.31	-	-
November 2	0.27	0.44	0.62	< 0.2	< 0.2
November 16	0.28	0.47	0.32	-	-
December 7	0.23	0.40	0.30	< 0.2	< 0.2
December 21	0.30	0.41	0.26	-	-

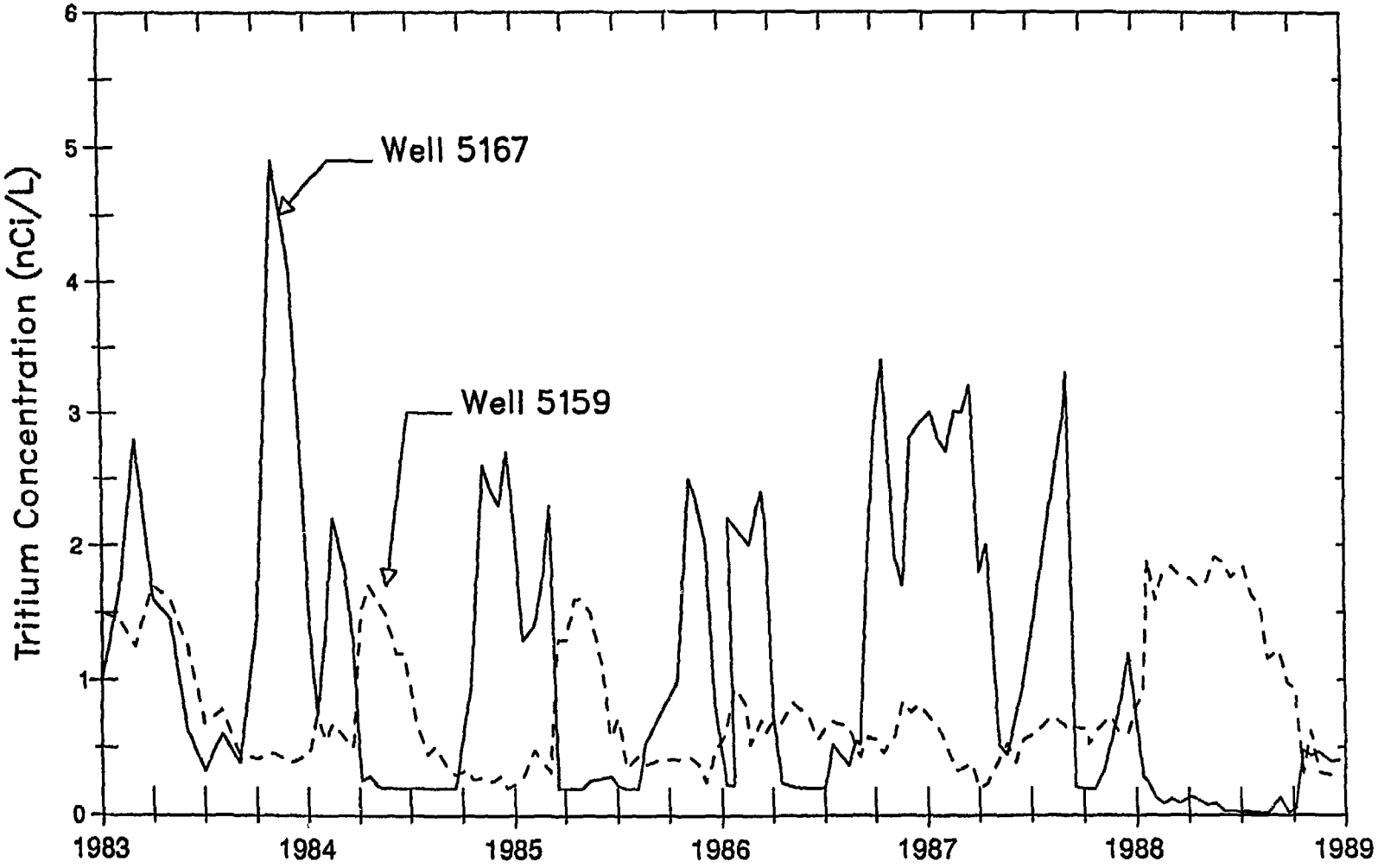

Figure 3.4 Tritiated Water Concentrations in Red Gate Woods Well (#5167) and Opposite Red Gate Woods (#5159) From 1983 Through 1988

pump handles due to high fecal coliform concentrations in the well water. Operational problems occurred during the summer with the guard well (#5215) which did not warrant repair or replacement of this well. Future sampling will not be conducted at this location unless monitoring at other wells indicates substantial changes in the tritium content. A set of picnic well water samples was collected on June 2, 1988, and November 10, 1988, 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, and #5232 in Figure 1.2. All the tritium results were less than the detection limit of 0.2 nCi/L.

The Red Gate Woods wells (#5167) and (#5160) are locations that provided the greatest potential radiation exposure to the public in 1988. If water equal to the Red Gate Woods well average concentration of 0.2 nCi/L were the sole source of water for an individual, the annual dose from the tritium would be 0.009 mrem. This is based on the EPA drinking water limit of a dose of 4 mrem/y, which results from the consumption of two liters of water per day at a concentration of 20 nCi/L.[9] If an individual consumed one liter of this water, the dose would be 1.3×10^{-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 analyzed for isotopic uranium, total alpha, total beta, strontium-90, and the transuranic nuclides. The total alpha (0.3 to 2.5 pCi/L) and total beta (3.9 to 20.7 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.

Samples were collected from the Red Gate Woods well (#5167) and analyzed for several inorganic constituents. The results are found in Table 3.11. Because the picnic wells are used as a drinking water supply, the limits used were the State of Illinois concentrations of chemical constituents in drinking water.[14] The constituents in Table 3.11 that do not have a

TABLE 3.10

Uranium Content of Well Water Near Plot M, 1988
(Concentrations in pCi/L)

Well Number*	Location	Date Collected			
		February 3	May 4	August 8	November 2
5160	Red Gate Woods North	-	-	0.06 ± 0.08	0.17 ± 0.11
5167	Red Gate Woods	0.68 ± 0.10	0.21 ± 0.08	0.46 ± 0.08	0.15 ± 0.14
5159	Opposite Entrance to Red Gate Woods	0.40 ± 0.13	0.27 ± 0.12	0.07 ± 0.07	0.21 ± 0.11
5158	300 yds NE of Entrance to Red Gate Woods	-	0.03 ± 0.09	-	-
5157	95th & Archer	-	1.60 ± 0.32	-	-

*See Figure 1.2.

TABLE 3.11

Inorganic Constituents in Red Gate Woods Well Water (#5167), 1988
(Concentrations in mg/L)

Inorganic Constituent	February	May	November	Limit**
Arsenic	< 0.01	< 0.01	< 0.01	0.05
Barium	0.03	0.04	0.03	1.0
Cadmium	0.0020	0.0005	0.0008	0.01
Chloride	7	9	21	250
Chromium	< 0.02	< 0.02	< 0.02	0.05
Copper	< 0.1	< 0.1	< 0.1	-
Fluoride	0.26	-	-	-
Iron	11.4	3.2	0.8	-
Lead	0.09	0.02	0.01	0.05
Manganese	0.062	0.026	< 0.01	0.15
Mercury*	-	< 0.1	< 0.1	2.0*
Nickel	< 0.04	< 0.04	< 0.04	-
pH	7.1	7.1	-	-
Silver	< 0.0001	0.0004	< 0.0001	0.05
Selenium	< 0.01	< 0.01	< 0.01	0.01
Sulfate	181	188	618	250
Zinc	10.05	7.91	2.12	-

*Concentrations in µg/L.

**State of Illinois concentrations of chemical constituents in drinking water.[14]

specific limit are provided for completeness. Although the limits are occasionally 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 can 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.

3.4 Bottom Sediment

Bottom sediment samples were collected from the stream next to Plot M at Location #1 and at Location #9 on August 5, 1988, and October 14, 1988. 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 plutonium-239 is slightly elevated downstream. However, the plutonium-239 concentration of 0.037 pCi/g, is similar to the fallout level. The concentrations are very low and the differences may reflect variations in the retentiveness of the bottom material.

3.5 Soil

During the spring of 1988, the Cook County Forest Preserve District conducted some site restoration work at Site A. This involved leveling some old foundation walls and covering any exposed concrete with soil. During this work, a buried 4,000 gallon fuel tank was discovered that was filled with liquid. A sample of the liquid indicated that it was essentially all water with a thin film of oil floating on top. Radiochemical analysis of the liquid gave 0.4 ± 0.1 nCi/L of tritium and no gamma-ray emitters. On April 19, 1988, the liquid was pumped from the tank and processed by an EPA licensed disposal firm. The buried fuel tank was removed on June 3, 1988, and properly disposed of by an EPA licensed firm. Based on visual inspection, the tank appeared to be intact. Soil samples were collected at four locations under the tank and analyzed for tritium and by gamma-ray spectrometry. The results are in Table 3.13. All the concentrations are within the normal range for that area.

TABLE 3.12

Radioactivity Content of Streambed Next to Plot M, 1988
(Concentrations in pCi/g)

Radionuclide	Date Collected	Location #1* (Upstream)	Location #9* (Downstream)
Potassium-40	August 5	20.85 ± 0.77	21.09 ± 0.78
	October 14	21.16 ± 0.64	18.45 ± 0.63
Strontium-90	August 5	0.18 ± 0.14	0.09 ± 0.03
	October 14	0.10 ± 0.03	0.10 ± 0.01
Cesium-137	August 5	0.26 ± 0.03	0.45 ± 0.03
	October 14	0.35 ± 0.03	0.45 ± 0.03
Radium-226	August 5	1.97 ± 0.08	2.06 ± 0.08
	October 14	1.74 ± 0.07	1.83 ± 0.07
Thorium-228	August 5	0.99 ± 0.04	1.02 ± 0.04
	October 14	0.97 ± 0.04	0.91 ± 0.04
Thorium-232	August 5	0.92 ± 0.10	0.93 ± 0.10
	October 14	0.90 ± 0.09	0.83 ± 0.09
Uranium-234	August 5	1.32 ± 0.13	1.24 ± 0.12
	October 14	1.20 ± 0.09	1.04 ± 0.09
Uranium-235	August 5	0.01 ± 0.01	0.01 ± 0.01
	October 14	0.01 ± 0.01	0.01 ± 0.01
Uranium-238	August 5	1.31 ± 0.13	1.03 ± 0.11
	October 14	1.26 ± 0.09	0.98 ± 0.09
Plutonium-238	August 5	0.0002 ± 0.0001	0.0013 ± 0.0003
	October 14	0.0007 ± 0.0002	0.0006 ± 0.0002
Plutonium-239	August 5	0.0092 ± 0.0008	0.0368 ± 0.0023
	October 14	0.0105 ± 0.0009	0.0327 ± 0.0017
Americium-241	August 5	0.0055 ± 0.0014	0.0040 ± 0.0010
	October 14	0.0014 ± 0.0007	0.0019 ± 0.0006

*See Figure 3.1.

TABLE 3.13

Soil Samples Collected During the Removal of the Fuel Tank on April 19, 1988

(Concentrations in pCi/g)

	Location			
Radionuclide	#1	#2	#3	#4
Hydrogen-3	0.04 ± 0.02	0.20 ± 0.02	0.08 ± 0.02	0.35 ± 0.02
Potassium-40	25.99 ± 0.82	19.98 ± 0.76	19.45 ± 0.83	6.33 ± 0.64
Cesium-137	< 0.03	< 0.03	< 0.03	< 0.03
Radium-226	1.56 ± 0.07	1.58 ± 0.07	1.44 ± 0.07	0.60 ± 0.06
Thorium-228	1.01 ± 0.04	0.95 ± 0.04	0.86 ± 0.04	0.26 ± 0.03
Thorium-232	1.02 ± 0.09	0.78 ± 0.09	0.76 ± 0.09	0.29 ± 0.08

Analysis of borehole water samples in 1986[7] and 1987[8] for inorganic and volatile organic constituents indicated that no hazardous waste materials are migrating from Plot M. However, these measurements could not answer the question of whether any hazardous materials were actually buried in Plot M. To address this issue, archived soil core samples collected in 1977[1] from a boring through the Plot M concrete cap were analyzed for metals. Five soil samples from Core #23, collected at various distances below the present surface, were analyzed by inductively coupled plasma/atomic emission spectrometry using Contract Laboratory Protocols. The results are collected in Table 3.14.

Based on past records, the waste is probably buried between three and nine feet below the surface. Therefore, sample 77S24 should be from within the waste, sample 77S27 at the bottom of the trench, and the other samples deeper. The general pattern is that some elements are slightly elevated within the burial area (sample 77S24) and constant at the lower depths; i.e., aluminum, barium, chromium, cobalt, lead, silver, and vanadium. However, there is no evidence of migration of these elements. All concentrations appear to be within the normal range of these elements in the earth's crust.

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 3.5 pCi/m^3 from 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 0.016 mrem. For the occasional visitor to Site A/Plot M, the 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 0.2 nCi/L would be 1.3×10^{-5} mrem; and consumption of one liter of water from Location #9 at the annual average concentration of 25.9 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

TABLE 3.14

Plot M Soil Samples - Core #23
(Concentrations in μg/g)

Sample Number	77S24	77S27	77S31	77S33	77S34
Depth (ft)	5-6.5	9.5-11	15.5-17	18.5-20	25-26.5
Aluminum	9460.0	6420.0	6040.0	5590.0	6690.0
Antimony	16.6	12.5	12.7	12.6	12.5
Arsenic	26.0	26.0	26.3	26.1	25.9
Barium	74.4	45.9	44.8	52.5	49.4
Beryllium	1.3	1.4	1.4	1.4	1.6
Cadmium	1.0	0.8	1.2	0.6	0.5
Calcium	18100.0	62200.0	63000.0	76000.0	83300.0
Chromium	21.8	16.4	16.7	16.1	17.7
Cobalt	17.3	10.9	13.2	12.6	9.5
Copper	29.4	23.6	28.3	21.7	17.8
Iron	21600.0	19200.0	21900.0	18400.0	18700.0
Lead	36.5	23.2	27.9	25.3	26.6
Magnesium	11800.0	29400.0	34300.0	36800.0	40100.0
Manganese	462.0	401.0	556.0	456.0	413.0
Nickel	32.7	27.6	30.3	29.0	23.7
Potassium	1560.0	1710.0	1840.0	1460.0	1980.0
Selenium	18.6	18.5	18.7	18.5	18.3
Silver	3.6	2.4	1.6	1.9	1.6
Sodium	95.6	125.0	151.0	114.0	133.0
Thallium	6.0	6.0	6.0	6.0	5.9
Vanadium	30.8	19.6	16.8	15.9	16.2
Zinc	70.0	63.4	77.3	56.9	56.3

of radiation. These are listed in Table 4.1. It is obvious that the magnitude of the doses received at Site A/Plot M 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.[15]

5.0 References

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(9) U. S. Environmental Protection Agency, "National Primary Drinking Water Regulations," 40 CFR Part 141, Federal Register, 50, pp. 46900, November 13, 1985.

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6.0 Appendices

6.1 Quality Assurance Program

All nuclear instrumentation is calibrated with standard sources obtained from the U. S. National Institute of Standards and Technology (NIST), if possible. If NIST standards were not available for particular nuclides, standards from the Amersham Corporation were used. The equipment is usually checked on a daily basis 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 or five different sample matrices containing various combinations of radionuclides. The results of our participation in both programs for 1988 are published in ANL-89/8.[12]

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 constituent sought. For example, samples for trace radionuclide analyses are acidified immediately after collection to prevent hydrolytic loss of metal ions.

6.2 Applicable Standards

The principle standard that is applicable to this study is the EPA drinking water standard 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 draft Order[10] 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-89/8.[12]

6.4 Acknowledgements

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