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Radon Concentrations Around the L-Bar Uranium Mill Site

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ABSTRACT

Measurements of radon concentrations were made between November 1985 and November 1986 in the vicinity of the uranium mill tailings pile of SOHIO L-Bar site near Seboyeta, New Mexico. The data can be used for exposure and risk estimates as discussed in the National Emission Standards for Hazardous Air Pollutants (NESHAP's) for radon-222 emission from licensed uranium mill tailings. Twenty-two Passive Environmental Radon Monitors (PERM's) were used in this investigation. They were placed 400, 600, and 800 meters away from the centroid of the pile. In addition, a background PERM station was established 1200 meters to the north and upwind from the centroid of the tailings. Radon concentrations were determined monthly by analyses of a pair of thermoluminescent dosimeters (TLD's) located in each PERM. Results of the data show that radon concentrations decreased with distance from the centroid of the tailings pile. During the year the average radon concentrations ranged between 14.9 Bq m^{-3} and 35.6 Bq m^{-3} at the 400 m interval, between 6.20 Bq m^{-3} and 18.8 Bq m^{-3} for 600 m, and at 800 m between 1.80 Bq m^{-3} and 9.80 Bq m^{-3}. The annual net radon concentrations at 600 and 800 meters were less than 18.5 Bq m^{-3}.

ACKNOWLEDGMENTS

Sample collection is always the unglamourous part of any study, but in reality is the most important aspect of an investigation. The authors are most appreciative and indebted to those persons who, despite inclement weather, collected the samples for analysis. They are Dr. Paul Hahn, Edith Boyd, Shirley Duran, Robert Lyon, and Roger Shura, who are staff members from the Office of Radiation Programs at the Las Vegas Facility.

We also thank the State of New Mexico, Environmental Improvement Division, for the support provided at the L-Bar site.

A special acknowledgment is accorded to Wayne Bliss, Director of ORP-LVF, for his strong support in this type of work.

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INTRODUCTION

The United States Environmental Protection Agency (EPA) on January 13, 1977 (42 FR 2858) published its response to public comments on the proposed "Environmental Radiation Protection Standards for Nuclear Power Operations." It was noted "...that doses resulting from exposure to radon and its daughters which are discharged from a mill site, or result from material which has been discharged, are excluded..." from these standards. The EPA on the same day promulgated standards (42 FR 2860) under Title 40, Code of Federal Regulations Part 190, Section 190.10 which exempted from control, radon and its decay products.

On September 30, 1983, the Agency issued standards under the Uranium Mill Tailings Radiation Control Act (UMTRCA) (40 CFR 192, Subparts D and E) for the management of tailings at active mills licensed by the Nuclear Regulatory Commission (NRC) or the States under Title II of the UMTRCA. These standards do not specifically limit radon-222 emissions until after closure of a facility; however, they require as low as reasonably achievable (ALARA) procedures for radon-222 control, and the NRC does consider ALARA procedures in licensing a mill. When the UMTRCA standards were promulgated, the Agency stated that it would issue an Advance Notice of Proposed Rulemaking with respect to control of radon-222 emissions from uranium tailings piles during the operational period of a uranium mill.

On April 6, 1983, emission radionuclide standards for NRC licensees were proposed under the Clean Air Act (48 FR 15076, April 6, 1983); however, uranium fuel-cycle facilities, which included operating uranium mills, were excluded because these sources are subject to EPA's 40 CFR Part 190 and 192 environmental health radiation standards. During the comment period for the Clean Air Act standards, it was noted that radon-222 emissions from operating uranium mills and tailings piles were not subject to any current or proposed EPA standards, and that such emissions could pose significant risks.

On October 31, 1984, EPA published an Advance Notice of Proposed Rulemaking (ANPR) in the Federal Register, 49 FR 43916, for radon-222 emissions from licensed uranium mills. The notice stated that the Agency is considering emissions standards for licensed uranium mills and solicited information in the following areas:

- Radon-222 emission rates from uranium mills and associated tailings piles

- Local and regional impacts due to emissions of radon-222 from uranium mills and associated tailings piles prior to permanent disposal

- Applicable radon-222 control options and strategies, including work practices

- Feasibility and cost of radon-222 control options and strategies

- Methods of determining compliance with a work practice type of standard to control radon-222 emissions

- Impact of radon-222 control on the uranium industry.

Prior to the publishing of this ANPR, the New Mexico Environmental Improvement Division (NMEID) conducted a 2-year indoor/outdoor radon concentration monitoring program in 1978 to 1980 in the Ambrosia Lake - Grants mineral belt area (Buhl et al. 1985). Additional sampling was done by the NMEID between March 1983 and May 1985 (NMEID 84, unpublished data). The NMEID asked the Office of Radiation Programs-Las Vegas Facility (ORP-LVF) to assist in surveying for radon in the environs of uranium mill sites in this State. At their request and in support of the Clean Air Act the ORP-LVF undertook a study to measure the Rn-222 concentration in the vicinity of SOHIO L-Bar uranium mill site.

Radon is released at the mill site during the crushing and grinding of the ore, as well as the extraction, recovery and concentration stages in which the "yellowcake" is produced. The ore storage area is an additional way for radon to emanate. However, the releases of radon from these sources are small relative to the tailings (EPA86) and will not be discussed in this report.

Tailings Disposal

With the exception of the uranium extracted during milling, the dry weight of the tailings represents the total dry weight of the processed ore. Ore contains only about 0.1 percent uranium; therefore, the tailings consist of 99.9 percent of the ore, including all the radioactive decay products. The tailings discharge is composed of three fractions: (1) the sands, which consist of solids larger than 200 mesh; (2) the slimes, which consist of solids smaller than 200-mesh; and (3) the liquid solution containing milling reagents and dissolved ore solids. Dry tailings from an acid leach mill are typically composed of 20 to 37 percent slimes by weight (NRC80). Tailings are discharged from the mill as a slurry at an average ratio, by weight, of about 1:1 (solids to liquids) and are sent to an impoundment, where the tailings settle.

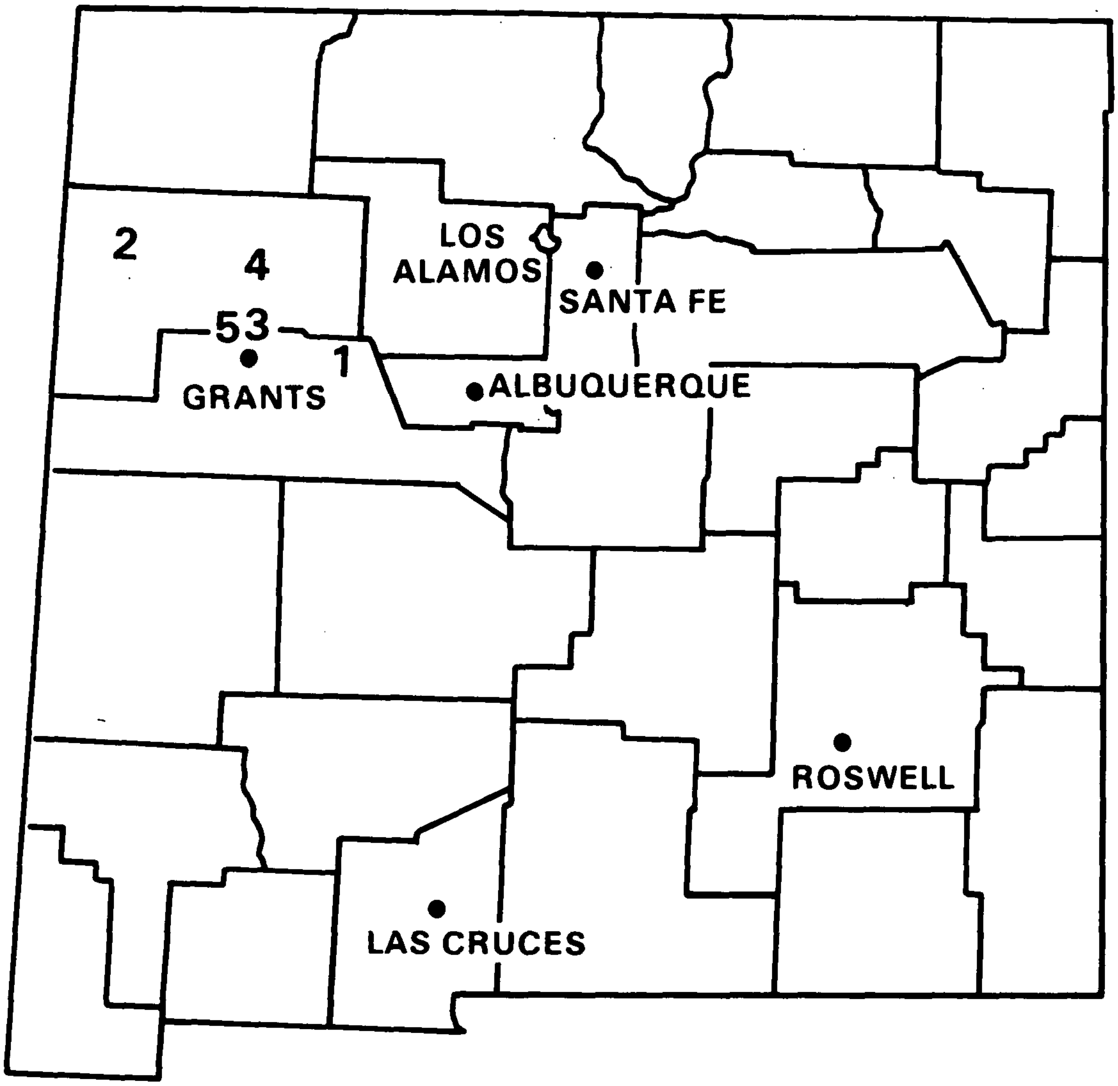
Approximately 10 percent of the uranium-238 and virtually all of the other radionuclides in the ore are contained in the tailings. Tailings represent the largest and longest lasting source of radon-222 emissions from licensed conventional uranium mills because of the large exposed areas and the significant presence of concentrated radium-226. The fraction containing the fine slimes makes up the majority of the radium-226 in the tailings (up to 80 percent) (NRC80). The sand fraction contains radium-226 concentrations from 26 to 100 pCi/gram (NRC80), and the tailings liquid (raffinate) of 1.7 to 35,000 pCi/liter for radium-226 and 50 to 250,000 pCi/liter for thorium-230 (EPA83).

L-Bar Mill

The SOHIO L-Bar uranium mill is located in the northwestern part of New Mexico, near Seboyeta in Cibola County. The mill site in an area of hilly terrain is about 71 km (44 miles) west of Albuquerque and 16 km (10 miles) north of Laguna, New Mexico. The general location of L-Bar is seen from Figure 1 of the different mills in New Mexico. Ore is obtained from an underground mine in the Jackpile sandstone formation. The mill used an acid-leach process and began operations in 1976, but since May 1981 has been on standby status (NRC84). The ore processing capacity of the mill is 1500 mt (1650 tons) per day. Ore reserves are adequate to provide for 10 to 15 years of operation. The ore grade varies from 0.05 to 0.30 percent U_3O_8 and averages 0.225 percent (NRC84). Size reduction of the ore is accomplished by semiautogenous grinding.

Mill tailings are contained in a single tailings impoundment. The L-Bar tailings dam was one of the last dams permitted in the industry in which the upstream construction method was used (Jo80). The tailings impoundment is built above grade with an earthen starter dam to the west that keys into natural topography on the north and south. A smaller saddle dam is constructed to the east. Tailings have been discharged to the impoundment from a single pipe that was moved along the dam. Coarse sands settled near the dike with the slimes deposited in the interior area. Water was decanted and pumped back to the mill. During operations, the edge of the tailings solution was maintained about 60 m (200 feet) from the dam crest. A light-track pressure dozer was used to construct raises with the sand tailings. The total site area covers 72 ha (180 acres) of which 51.8 ha (128 acres) are tailings (NRC84). Approximately 11.3 ha (28 acres) of the tailings are covered with tailings solution (EPA85). The impoundment consists of about 1.5×10^6 mt (1.6×10^6 tons) of tailings (Jo80). The tailings are reported to contain 500 pCi/g of radium-226 (EPA83).

During operations, ore is stockpiled at the mill on an ore pad and apron feeder. However, since 1981 when the plant went to a standby status, no ore has been stored in these areas except for a short supply which has been stored north of the tailings area (NM85).



1 Sohio
L-Bar Mill

2 United Nuclear Corp.
Churchrock Mill

3 Anaconda Minerals Co.
Bluewater Mill

4 Kerr-McGee Nuclear Corp.
Quivira Mill

5 Homestake Mining Co.
Homestake Mill

Figure 1. Map of locations of the uranium mills in New Mexico.

The surrounding area is sparsely populated. The results of a 1983 population survey showed no individuals lived within a 3-km (1.9 mi) radius of the tailings impoundment, while 42 and 129 people resided between 3 and 4-km (1.9 and 2.5 mi) and between 4 and 5-km (2.5 and 3.1 mi) away from this impoundment, respectively (PNL84).

Estimating Emissions

Estimates of radon-222 emissions are based on an assumed emission rate that equals the specific flux of 1 pCi radon-222/m^2s for each pCi radium-226/g of dry tailings times the dry area (NRC80). It has been assumed that tailings which are either saturated with or covered by tailings solution do not emit radon-222. These assumptions were applied to the site-specific data to estimate emissions.

The L-Bar tailings pile consists of 51.8 ha (128 acres) of which 11.3 ha (28 acres) are ponded, 22.3 ha (55 acres) wet, and 18.2 ha (45 acres) dry beach. In the Background Information Document (EPA86), it was estimated that the release of Rn-222 was between 3-4 kCi/yr.

The dam for the impoundment area of this mill site is constructed from coarse tailings material. The total tailings surface area is 51.8 ha (128 acres) with an average activity of 500 pCi/g of Ra-226 (EPA83). It was predicted that 11 kCi/y of Rn-222 is released from a 57 ha (140 acres) tailings pile that contained 1.9 x 10^6 mt material lined with natural clay, and an annual rainfall and evaporation of 8" and 56", respectively (EPA86). This predicted scenario closely approximates the L-Bar site.

Study Objective

This study was made to determine the concentration of radon-222 in the vicinity of a licensed uranium mill tailings pile. The data can be used for exposure and risk estimates as discussed in the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radon-222 emission from licensed uranium mill tailings.

METHOD

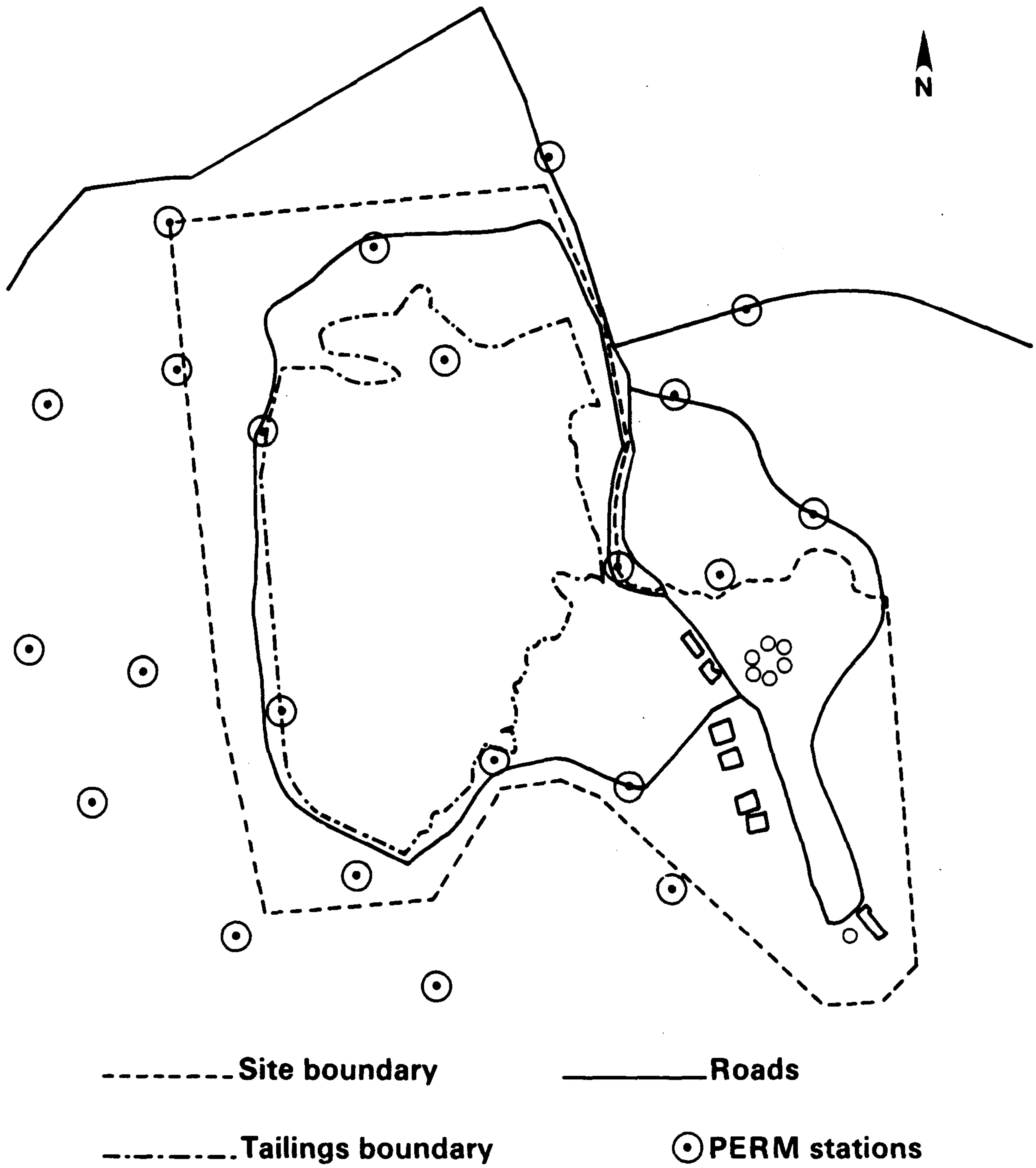
The L-Bar mill site was selected as the study area because of its small tailings size (51.8ha) and readily measureable radium activity (500 pCi/g). A description of the site is discussed earlier in this report.

Twenty-two Passive Environmental Radon Monitors (PERM's) (Ge77, Ho84) were placed in the area of the tailings pile of L-Bar (Figure 2). The sampling design was a circular one with the PERM's located at distances of 400, 600, and 800 meters away from the centroid of the pile. Five samplers were located at the 400 meter distance at equal intervals from one another. Seven samplers were equally spaced at the 600 meters distance and ten samplers were placed at the 800 meters distance. Thus the samplers were placed approximately the same arc length from one another. Each PERM was housed in a protective structure and placed at a height of one-meter above the ground. An additional pair of PERM's was used for the background station which was established 1200 meters to the north and upwind from the centroid of the tailings. During the period of this study, two extra PERM's were placed adjacent to the previously established stations. These additional PERM's were for quality assurance (QA). The availability of PERM's dictated the extent of the QA program for this study.

Radon concentrations were determined monthly by analyses of a pair of thermoluminescent dosimeters (TLD) located in each PERM. There were 500 TLD measurements made during the period of the study from November 1985 to November 1986. Over 300 soil and tailings samples were taken and gamma counted primarily for radium-226 activity. The discussion of the analytical results of the soil and tailings samples will be presented in other reports.

RESULTS AND DISCUSSION

In our discussion, radon and radon-222 are considered synonymous and the former shall be used whenever concentration values are presented.



Scale: 1 inch equals approximately 340 meters

Figure 2. Map of the locations of the PERM stations at the L-Bar site.

The radon concentration values (Bq m^{-3}), the distance and the azimuthal direction of the individual sampling location are given in Table 1. The radon values are for each month of the study which began on 11/15/85 and ended on 11/20/86. The distance and azimuthal directions of each location were taken from the centroid of the tailings pile. The annual and net annual averages of radon values are presented in Table 2. At the 1200-meter distance, the annual average radon value was 11.8 Bq m^{-3} (0.32 pCi l^{-1}). The radon value of 30.0 Bq m^{-3} (0.81 pCi l^{-1}) at this sample location during the period of November 15 to December 17, 1985, is unusually high compared to the other values obtained at this location during the course of the study. This data point which is greater than 3s (standard deviation) above the average background value is considered an outlier and is not used in our discussion of the radon concentrations for the L-Bar site.

The data of net radon concentrations are contour plotted using the Surface II program and are presented in Figures 3 to 7 for the four different sampling quarters as well as the entire year's study. All contour plots are in the same direction and scale as Figure 2. Generally, the data in all of these figures indicated higher radon activity in the two sampling locations on the south end of the tailings pile than at the northern locations at the 400 meter interval. It should be stated that four of the five sampling stations at the 400 meter distance are on the edge of the tailings; and the depth of the tailings material ranged from about 6" (15 cm) in the northern part to about 50' (15 m) in the south. Thus this difference in radon values may be related to a larger volume of tailings resulting in a greater emanation of radon.

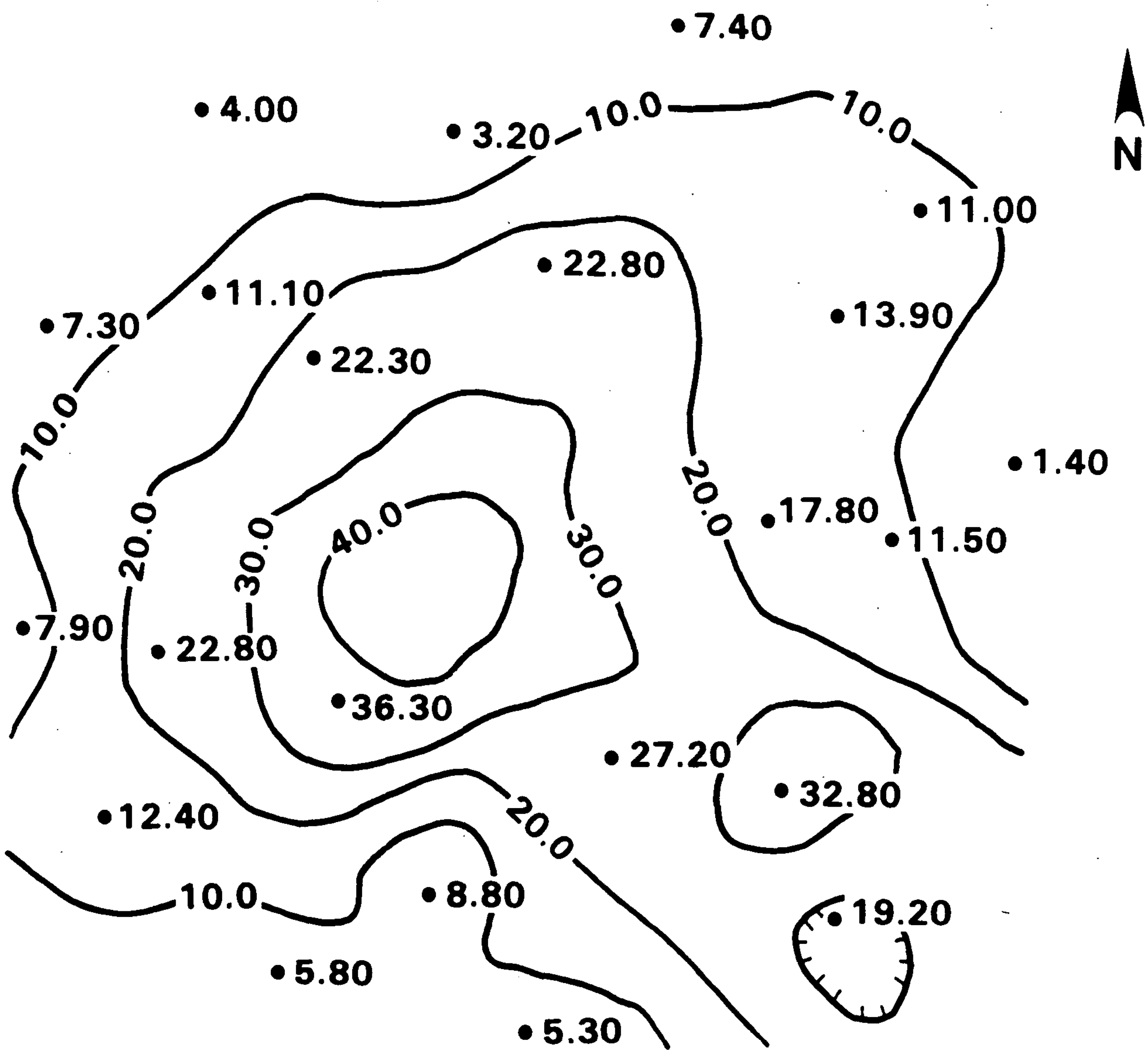
Also in these figures, the isoconcentration values of radon show an elongation toward the northeastern portion of the tailings pile which is usually the direction of the prevailing diurnal wind. On the other hand, the elevated radon level in the southwestern direction is due to the nocturnal drainage or gravity flow from the pile to the lower terrain surrounding the site.

TABLE 1. MONTHLY RADON CONCENTRATION AT L-BAR (Nov. 1985 - Nov. 1986)
(Bq m^{-3})

	1985	1985-1986	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986
Location	11/15-12/17	12/17-1/16	1/16-2/19	2/19-3/20	3/20-4/23	4/23-5/23	5/23-6/24	6/24-7/25	7/25-8/26	8/26-9/25	9/25-10/26	10/26-11/20
400m-E	27.4	41.4	27.4	24.8	20.4	—	29.2	21.8	27.8	31.1	32.9	39.6
400m-SSE	40.0	44.0	40.3	24.4	40.3	—	36.3	48.8	45.1	56.2	54.0	32.9
400m-SSW	55.1	49.6	47.0	23.7	41.4	28.5	—	74.0	49.2	48.8	64.8	14.1
400m-NW	30.7	65.9	13.0	20.0	18.1	15.9	12.2	45.5	23.3	38.5	41.1	34.0
400m-N	36.6	54.0	20.7	13.0	24.8	24.1	24.1	24.1	28.5	37.0	14.4	12.2
600m-E	20.7	36.6	20.0	14.4	16.7	13.3	15.5	17.0	—	—	—	15.5
600m-SE	—	66.6	27.0	17.4	20.0	13.7	25.2	20.0	21.1	48.8	24.8	27.4
600m-SW	19.2	28.1	21.8	8.1	10.0	10.7	12.2	13.3	19.6	18.9	18.9	32.9
600m-WSW	26.6	57.4	26.6	12.6	31.1	10.7	17.0	26.3	22.6	31.5	21.8	37.7
600m-W	22.2	35.5	18.5	5.6	10.4	11.1	15.2	18.1	16.7	16.7	19.2	23.7
600m-NNW	15.2	20.4	16.7	8.1	—	8.5	10.4	11.1	12.6	15.2	12.2	17.0
600m-NNW							—	—	3.7	11.5	12.2	18.9
600m-NE	25.9	32.2	26.3	17.8	30.0	29.2	31.1	28.5	—	22.9	24.1	26.6
800m-E	12.2	21.5	—	8.5	11.8	11.5	12.2	14.1	—	12.2	10.4	21.5
800m-SE	24.4	44.8	31.1	13.0	4.1	—	—	—	12.6	14.8	19.2	21.5
800m-SE							—	—	13.3	19.6	—	—
800m-S	10.7	23.7	24.4	4.1	7.0	14.1	11.8	12.6	10.7	14.1	11.5	13.3
800m-SSW	17.4	24.4	18.5	8.9	10.7	11.1	19.2	9.6	15.5	15.2	20.4	21.5
800m-WSW	23.7	33.7	22.6	13.3	15.9	13.0	15.9	18.9	18.5	18.9	31.8	26.3
800m-W	20.7	32.2	13.7	13.0	14.4	10.0	12.6	16.7	—	18.1	24.4	21.5
800m-WNW	30.0	20.7	14.1	14.1	5.2	—	—	—	9.3	18.9	16.3	23.3
800m-NW	14.1	22.9	17.8	7.8	8.9	8.1	10.0	9.3	13.7	16.7	14.1	20.4
800m-NNE	23.3	25.5	16.3	14.8	9.6	10.0	9.3	15.5	—	15.5	13.7	15.9
800m-NE	27.4	29.2	19.2	15.5	12.6	12.6	15.9	20.4	27.8	22.6	15.9	18.5
1200m-NNE	30.0	16.3	13.0	5.9	6.7	6.3	11.1	9.6	9.3	8.5	15.5	17.8
1200m-NNE	14.8	15.9	10.7	7.0	8.9	5.9	14.8	—	—	—	—	13.3

TABLE 2. ANNUAL AVERAGE RADON CONCENTRATION AT L-BAR (Bq m^{-3})

Location	Annual Average	Net Annual Average
400m-E	29.6	18.5
400m-SSE	42.2	31.1
400m-SSW	45.1	34.0
400m-NW	29.2	18.1
400m-N	26.6	15.5
600m-E	18.9	7.8
600m-SE	28.5	17.4
600m-SW	17.8	6.7
600m-WSW	26.6	15.5
600m-NW	17.8	6.7
600m-NNW	13.3	2.2
600m-NE	26.6	15.5
800m-E	13.7	2.6
800m-SE	22.6	11.5
800m-S	13.3	2.2
800m-SSW	15.9	4.8
800m-WSW	21.1	10.0
800m-W	17.8	6.7
800m-WNW	17.0	5.9
800m-NW	13.7	2.6
800m-NNE	15.5	4.4
800m-NE	19.6	8.5
1200m-NNE	11.1	Bkgd



Scale: 1 inch equals approximately 340 meters

Figure 3. Average net radon concentrations and isoconcentration contours for the first quarter. (Numbers expressed in Bq m^{-3})

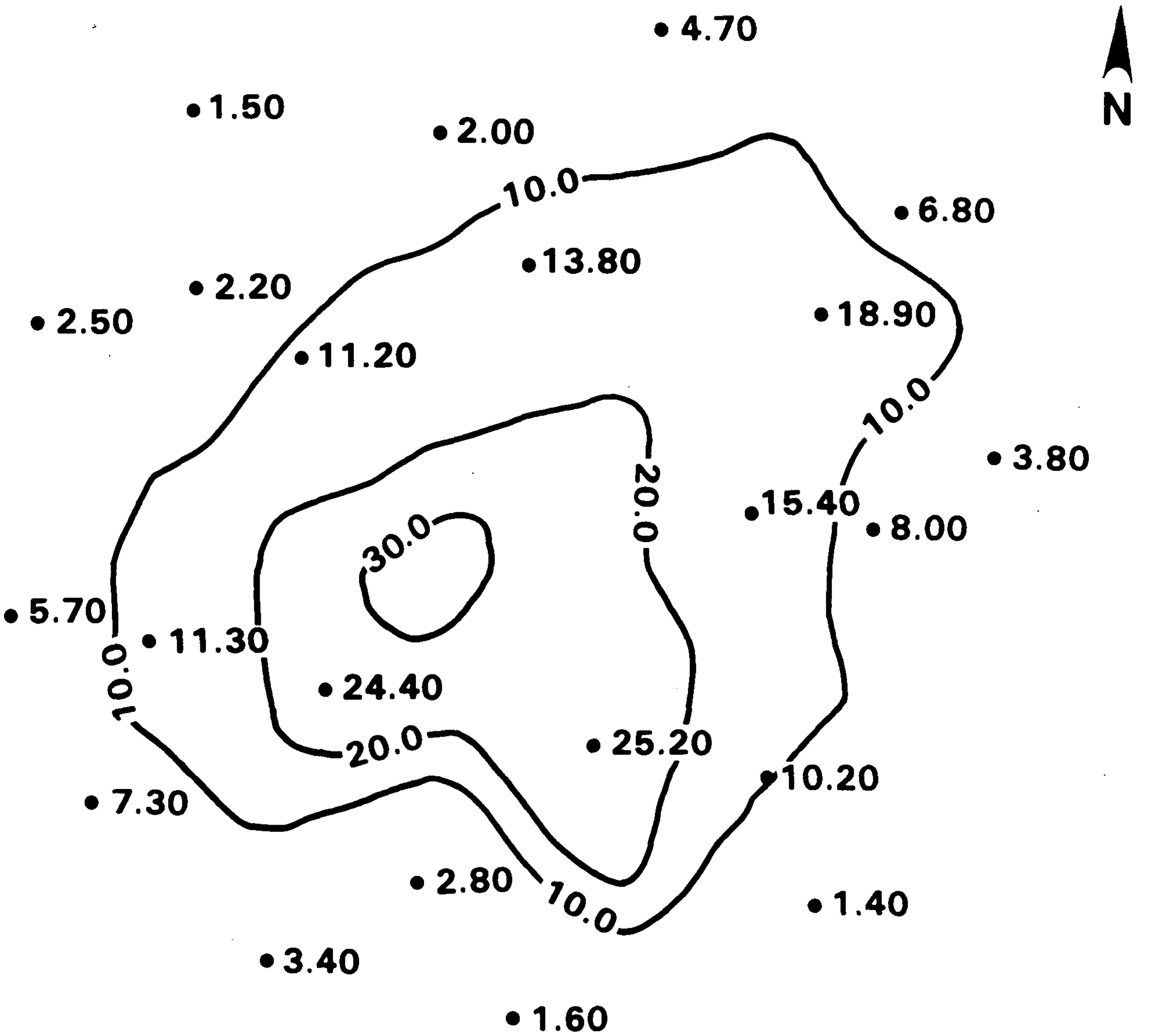


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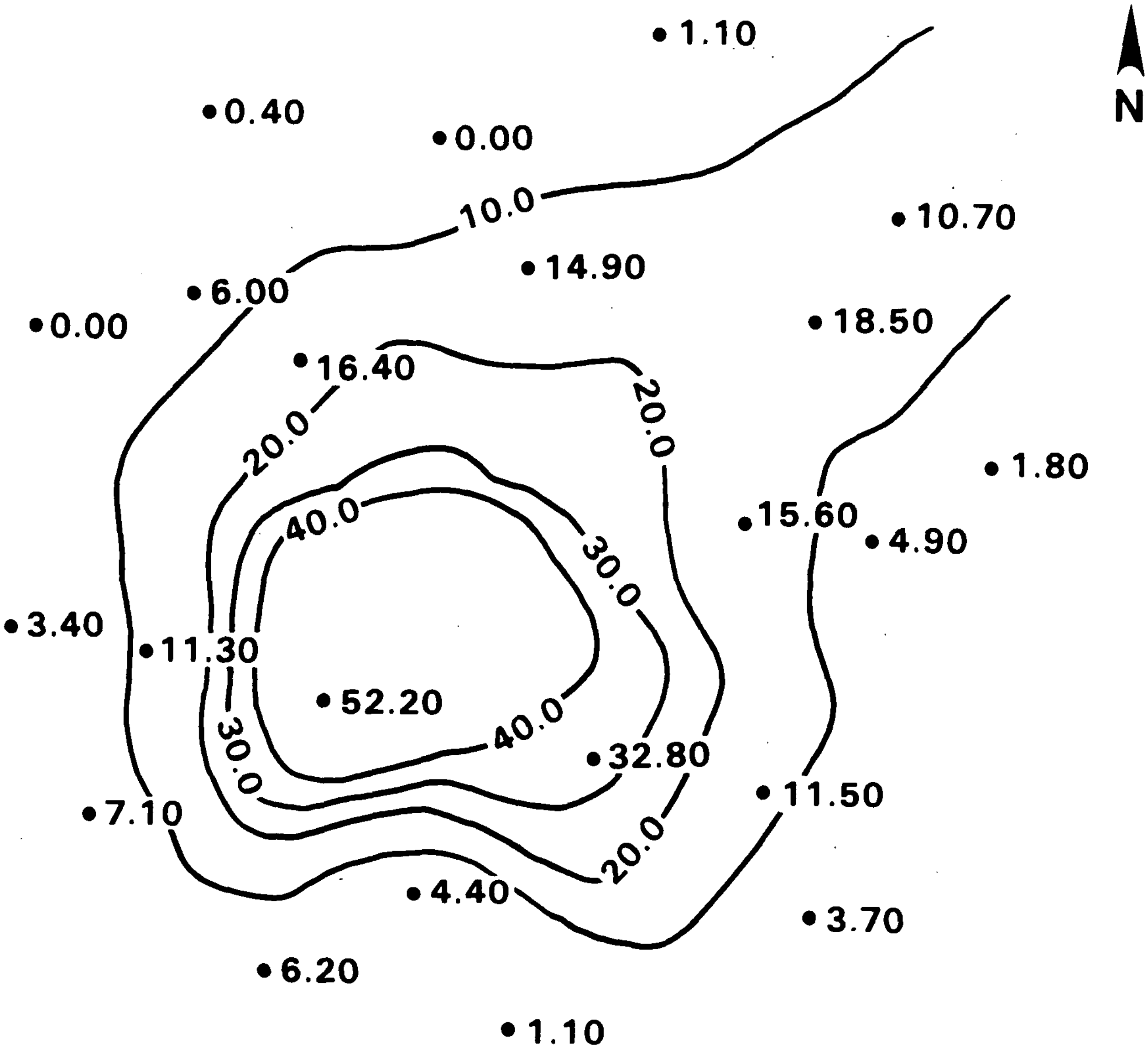
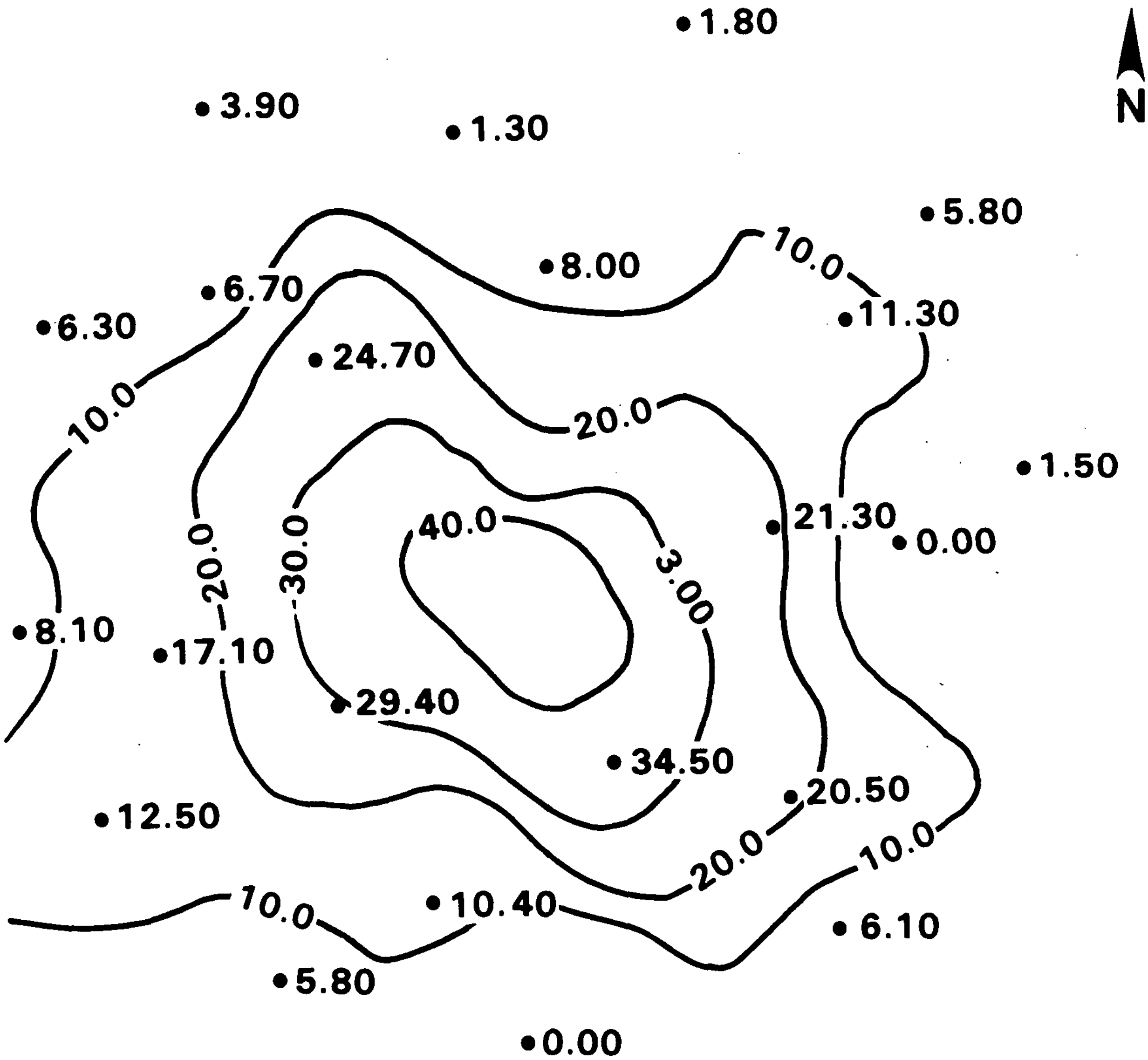
Figure 4. Average net radon concentrations and isoconcentration contours for the second quarter. (Numbers expressed in Bq m^{-3})



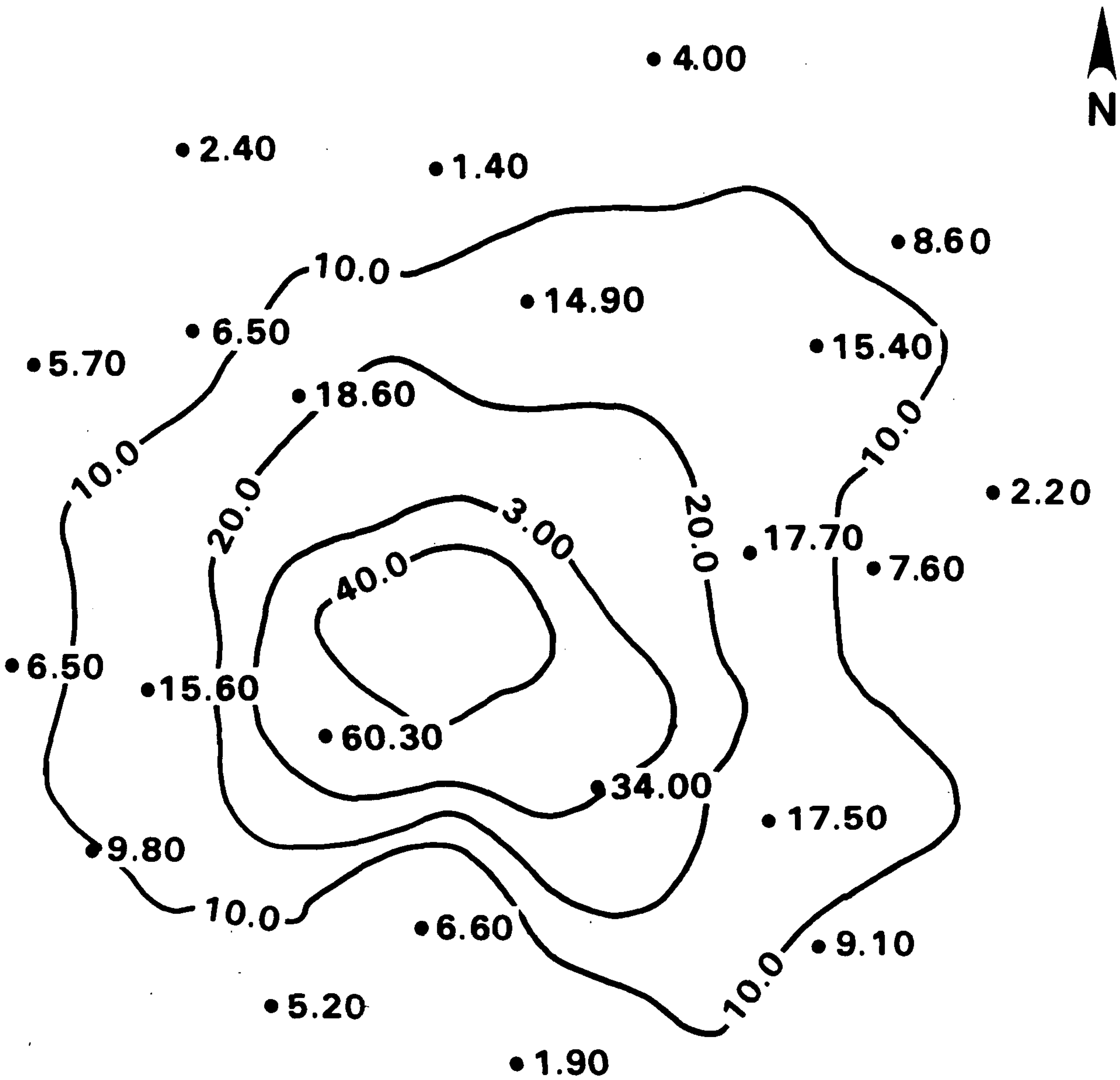
Scale: 1 inch equals approximately 340 meters

Figure 5. Average net radon concentrations and isoconcentration contours for the third quarter. (Numbers expressed in Bq m^{-3})



Scale: 1 inch equals approximately 340 meters

Figure 6. Average net radon concentrations and isoconcentration contours for the fourth quarter. (Numbers expressed in Bq m^{-3})



Scale: 1 inch equals approximately 340 meters

Figure 7. Average net radon concentrations and isoconcentration contours for the entire study (11/15/85 to 11/20/86). (Numbers expressed in Bq m^{-3})

In Figure 7, entire year's study, the radon concentrations decreased with distance from the centroid of the uranium tailings pile. There is a decrease in radon activity by about a factor of 2 between the 400 and 600 meter interval, about a factor of 4 between the 400 and 800 meter distance, and about a factor of 2 between the 600 and 800 meter intervals. During the year the average radon concentrations at the different sampling distances ranged betweeen 14.9 Bq m^{-3} (0.40 pCi l^{-1}) and 35.6 Bq m^{-3} (0.96 pCi l^{-1}) at the 400 m interval, between 6.20 Bq m^{-3} (0.17 pCi l^{-1}) to 18.8 Bq m^{-3} (0.51 pCi l^{-1}) for 600 m, and between 1.80 Bq m^{-3} (0.05 pCi l^{-1}) and 9.80 Bq m^{-3} (0.26 pCi l^{-1}) at 800 meters (Figure 7).

In Figure 8, the average radon concentrations at 400, 600, 800, and 1200 meters are graphically presented for each month of the study, beginning November 15, 1985 and ending November 20, 1986. The data show the highest radon activity occurred in the first sampling quarter, followed by the third and fourth quarters which had similar patterns of activity, and the lowest activity in the second quarter. Also, there is a definite decrease of radon concentration with increasing distance from the centroid of the tailings pile.

Earlier in our discussion, we stated that most of the PERM stations at the 400 meter distance were established on the edge of the mill tailings pile, whereas those at 600 and 800 meters were not near the edge. In fact, several were located as far away as the perimeter of the site boundary. The net annual radon concentrations as seen in Figure 8 were less than 18.5 Bq m^{-3} (0.5 pCi l^{-1}) at the 600 and 800 meter intervals.

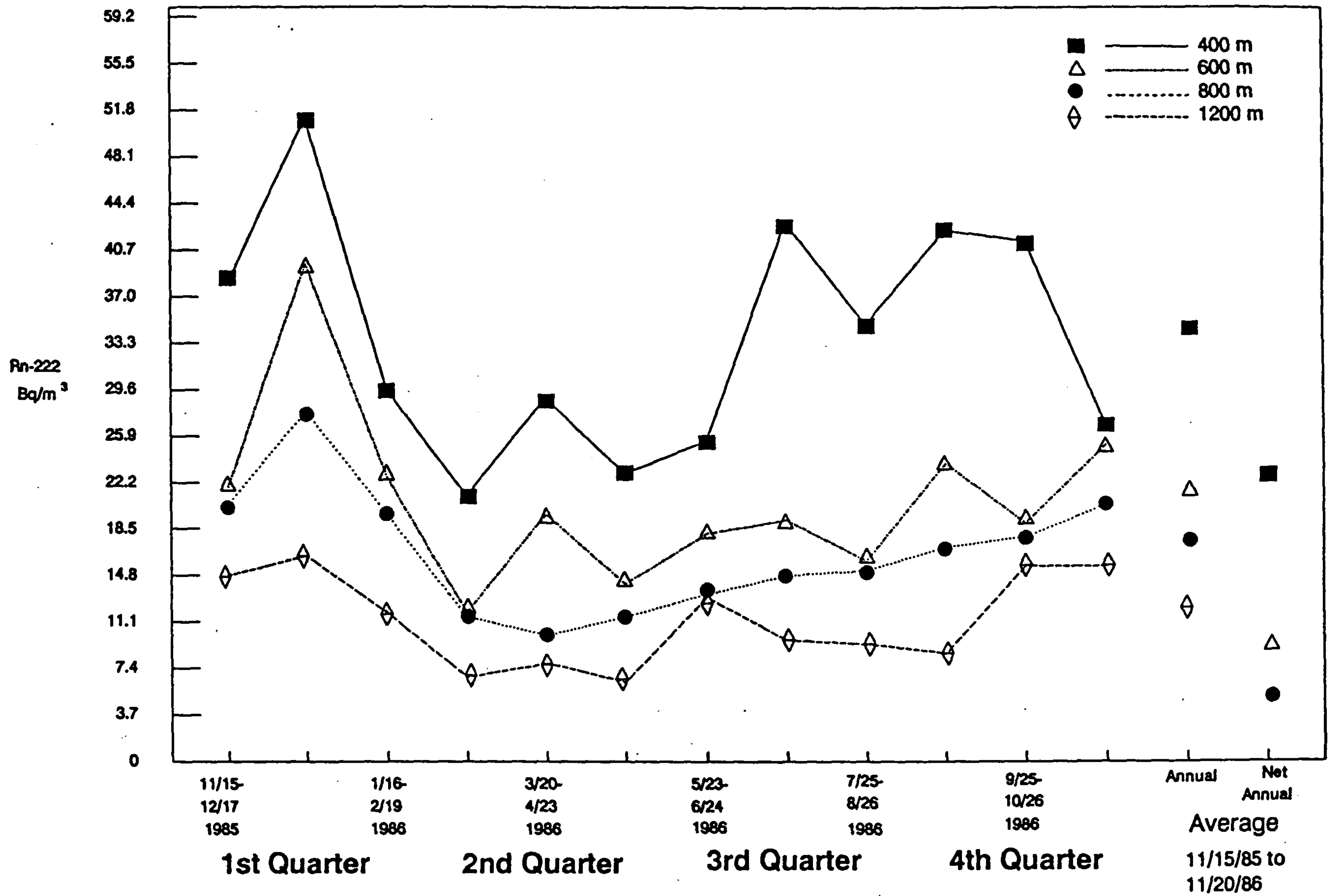


Figure 8. Gross monthly average radon concentrations at sampling locations at the 400m, 600m, 800m, and 1200 meter distances.

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