DOE/OR/20722-99
REV. 1

Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-81OR20722

HAZELWOOD INTERIM STORAGE SITE ANNUAL SITE ENVIRONMENTAL REPORT

Hazelwood, Missouri

Calendar Year 1985

April 1986
Revised November 1986

Bechtel National, Inc.
Advanced Technology

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Rev. 1

HAZELWOOD INTERIM STORAGE SITE
ANNUAL SITE ENVIRONMENTAL REPORT
CALENDAR YEAR 1985

APRIL 1986

REVISED NOVEMBER 1986

Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

Under Contract No. DE-AC05-81OR20722

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ABSTRACT

During 1985, the environmental monitoring program was continued at the Hazelwood Interim Storage Site (HISS), a U.S. Department of Energy (DOE) facility located in the City of Hazelwood, Missouri. The HISS is presently used for the storage of low-level radioactively contaminated soils. Monitoring results show that the HISS is in compliance with DOE Derived Concentration Guides (DCGs) and radiation protection standards. Derived Concentration Guides represent the concentrations of radionuclides in air or water that would limit the radiation dose to 100 mrem/yr, the DOE radiation protection standard for long-term exposure of the public. The applicable limits have been revised since the 1984 environmental monitoring report was published. The limits applied in 1984 were based on a radiation protection standard of 500 mrem/yr; the new DOE limits appplied for 1985 are based on a standard of 100 mrem/yr for long-term exposure and 500 mrem/yr for short-term exposure (i.e., less than 5 years).

The HISS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a DOE program to decontaminate or otherwise control sites where low-level radioactive contamination remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has mandated DOE to remedy. As part of the research and development decontamination program authorized by Congress under the 1984 Energy and Water Appropriations Act, remedial action is being conducted at the site and at vicinity properties by Bechtel National, Inc. (BNI), Project Management Contractor for FUSRAP. The environmental monitoring program is also carried out by BNI.

To determine whether the site is in compliance with DOE standards, environmental measurements are expressed as percentages of the applicable DCG, while the calculated doses to the public are expressed as percentages of the applicable radiation protection standard.

The monitoring program at the HISS measures uranium, radium, and thorium concentrations in surface water, groundwater, and sediment; radon gas concentrations in air; and external gamma radiation exposure rates. Potential radiation doses to the public are also calculated.

During 1985, annual average radon concentrations ranged from 10 to 23 percent of the DCG. The highest external dose rate at the HISS was 287 mrem/yr. The measured background dose rate for the HISS area is 99 mrem/yr. The highest average annual concentration of uranium in surface water monitored in the vicinity of the HISS was 0.7 percent of the DOE DCG; for radium-226 it was 0.3 percent of the applicable DCG, and for thorium-230 it was 1.7 percent. In groundwater, the highest annual average concentration of uranium was 12 percent of the DCG; for radium-226 it was 3.6 percent of the applicable DCG, and for thorium-230 it was 1.8 percent. While there are no concentration guides for stream sediments, the highest concentration of total uranium was 19 pCi/g, the highest concentration of radium-226 was 4 pCi/g, and the highest concentration of thorium-230 was 300 pCi/g.

The HISS was designated for remedial action under FUSRAP because radioactivity above applicable limits was found to exist at the site and its vicinity. Elevated levels of radiation still exist in areas where remedial action has not yet been completed. Detailed explanations regarding radiation levels measured in 1985 can be found in the summary in Section 2.0 and the technical discussion in Section 3.0.

Radon concentrations, external gamma dose rates, and radionuclide concentrations in groundwater at the site were lower than those measured in 1984; radionuclide concentrations in surface water were roughly equivalent to 1984 levels. For sediments, a meaningful comparison with 1984 concentrations cannot be made since samples were obtained at only two locations and were only analyzed for thorium-230.

The calculated radiation dose to the maximally exposed individual at the HISS, considering several exposure pathways, was 5.4 mrem, which is 5 percent of the radiation protection standard.

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1.0 INTRODUCTION

This report presents the findings of the environmental monitoring conducted at the Hazelwood Interim Storage Site (HISS) during calendar year 1985. Environmental monitoring has been conducted at the HISS since 1984. As part of the research and development decontamination program authorized by Congress under the 1984 Energy and Water Appropriations Act, Bechtel National, Inc. is conducting remedial action on-site and at vicinity properties. The work is being performed as part of the U.S. Department of Energy (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP), one of four remedial action programs under the direction of the DOE Division of Facility and Site Decommissioning Projects.

1.1 LOCATION AND DESCRIPTION

The HISS is located in northern St. Louis County within the city limits of Hazelwood, Missouri, at 9200 Latty Avenue (Figure 1-1). The vicinity properties lie along Latty Avenue from Coldwater Creek to Interstate Highway 170 in Hazelwood. Some of the vicinity properties are located within the corporate limits of the adjacent city of Berkeley. The HISS lies 3.2 km (2 mi) northeast of the control tower of the Lambert-St. Louis International Airport. An aerial photograph of the HISS and its vicinity is shown in Figure 1-2.

The HISS is located in a broad, shallow oval-shaped depression known as the Florissant Basin. During glacial times drainage from the area was blocked, and the Florissant Basin was a lake in which silts, clays, and sands were deposited to a depth of approximately 30.5 m (100 ft). The general characteristics of the upper soil types include seasonally high water tables, marginal to slow percolation rates, poor bearing capacity, high compressibility, very high available water capacity, poor surface and internal drainage, and high organic content (Ref. 1).

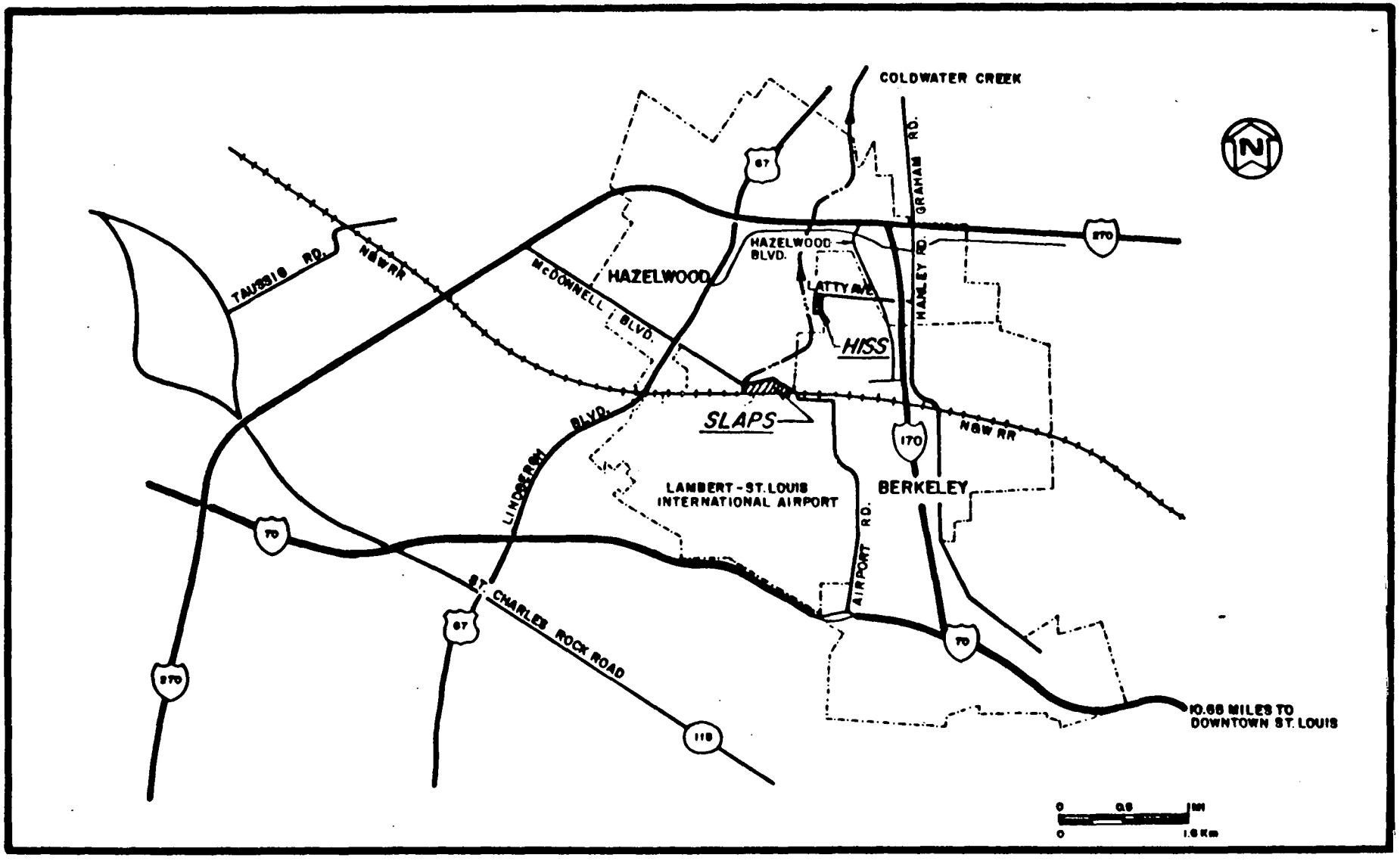


FIGURE 1-1 LOCATION OF THE HISS

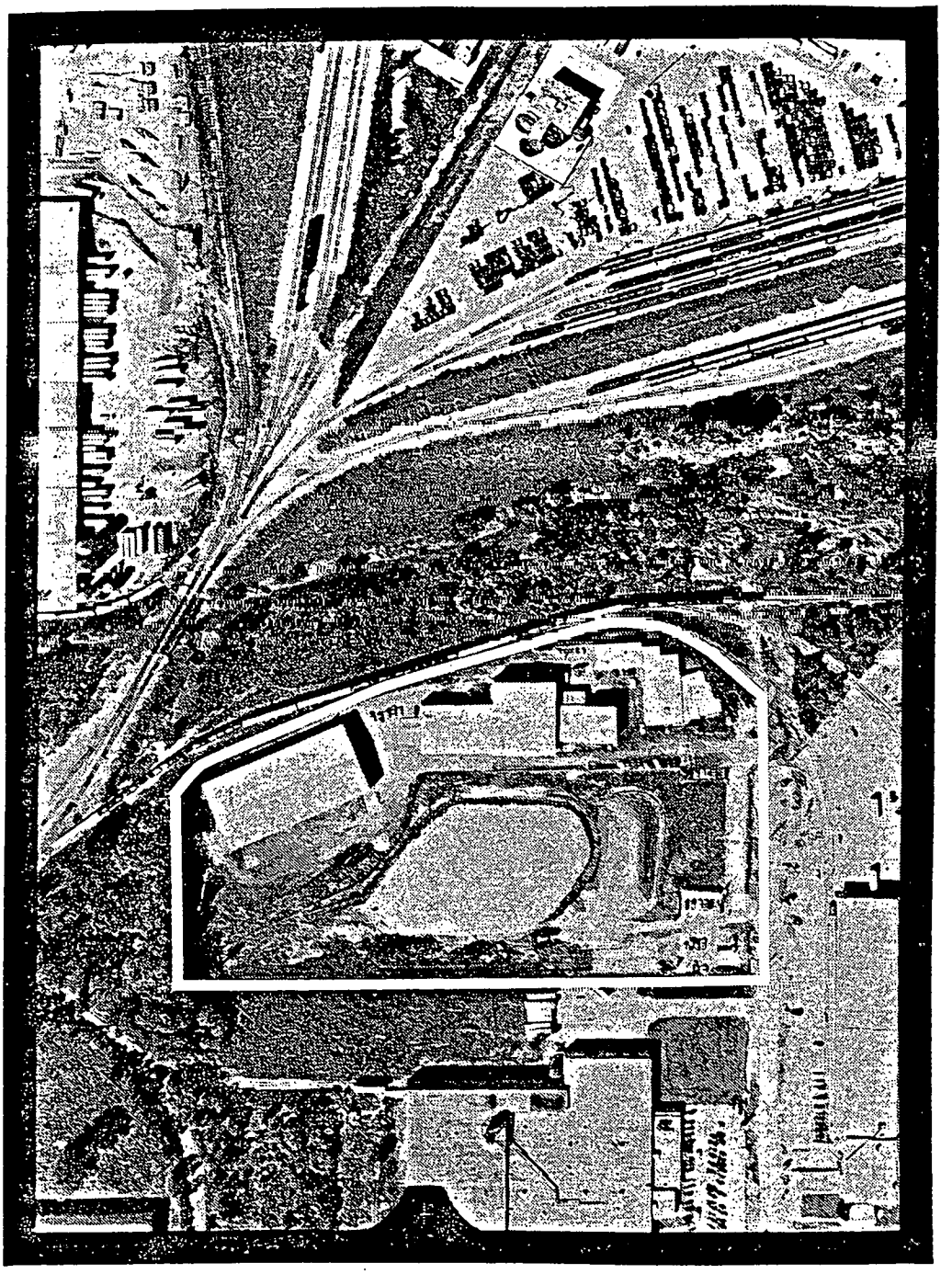


FIGURE 1-2 AERIAL VIEW OF HISS AND ITS VICINITY

Surface water runoff follows surface elevation contours and flows to the north and the south across the site. Water flowing to the north enters storm drainage ditches on both sides of Latty Avenue before discharging into Coldwater Creek, the main receiving body for site runoff. Water flowing to the south leaves the site via two ditches, one located near the western boundary of the site, the other near the southeastern boundary. These ditches flow into an unnamed tributary before discharging into Coldwater Creek. The 100-yr flood elevation for the HISS is approximately 158.5 m (520 ft) above sea level (Ref. 2). Portions of the site are, therefore, located in the 100-yr floodplain.

Groundwater in the Hazelwood area is available primarily from bedrock aquifers and from unconsolidated deposits in the overlying strata. In the area surrounding the HISS, water content of the subsoils is very high, but percolation rates are low. Thus, the area has virtually no potential for groundwater development from shallow wells (Ref. 1). Treated surface water from the Mississippi River is used for municipal drinking water in this area (Ref. 3). Groundwater flow in the vicinity of the site generally follows surface topography and thus flows toward Coldwater Creek (Ref. 1).

The average annual daily maximum temperature for the HISS area is 18.6°C (65.5°F), and the average daily minimum is 7.4°C (45.4°F). The highest average monthly temperature is 31.7° (89°F) (July) and the lowest is -6.7°C (19.9°F) (January). Average annual precipitation is 85 cm (34 in.), with an average annual snowfall of 65.8 cm (26.3 in.) (Ref. 4). As shown in Figure 1-3, prevailing winds in the vicinity of the HISS were from the south during the summer and fall. Wind speeds during these months averaged 13.9 km/h (8.7 mph). Winds during the winter months were from the northwest and west-northwest, averaging 17.6 km/h (11 mph) (Refs. 4, 5).

The residential areas nearest the site are approximately 0.5 km (0.3 mi) east in the City of Hazelwood. Residences in the City of Berkeley lie southeast of the site. In 1980, the populations of

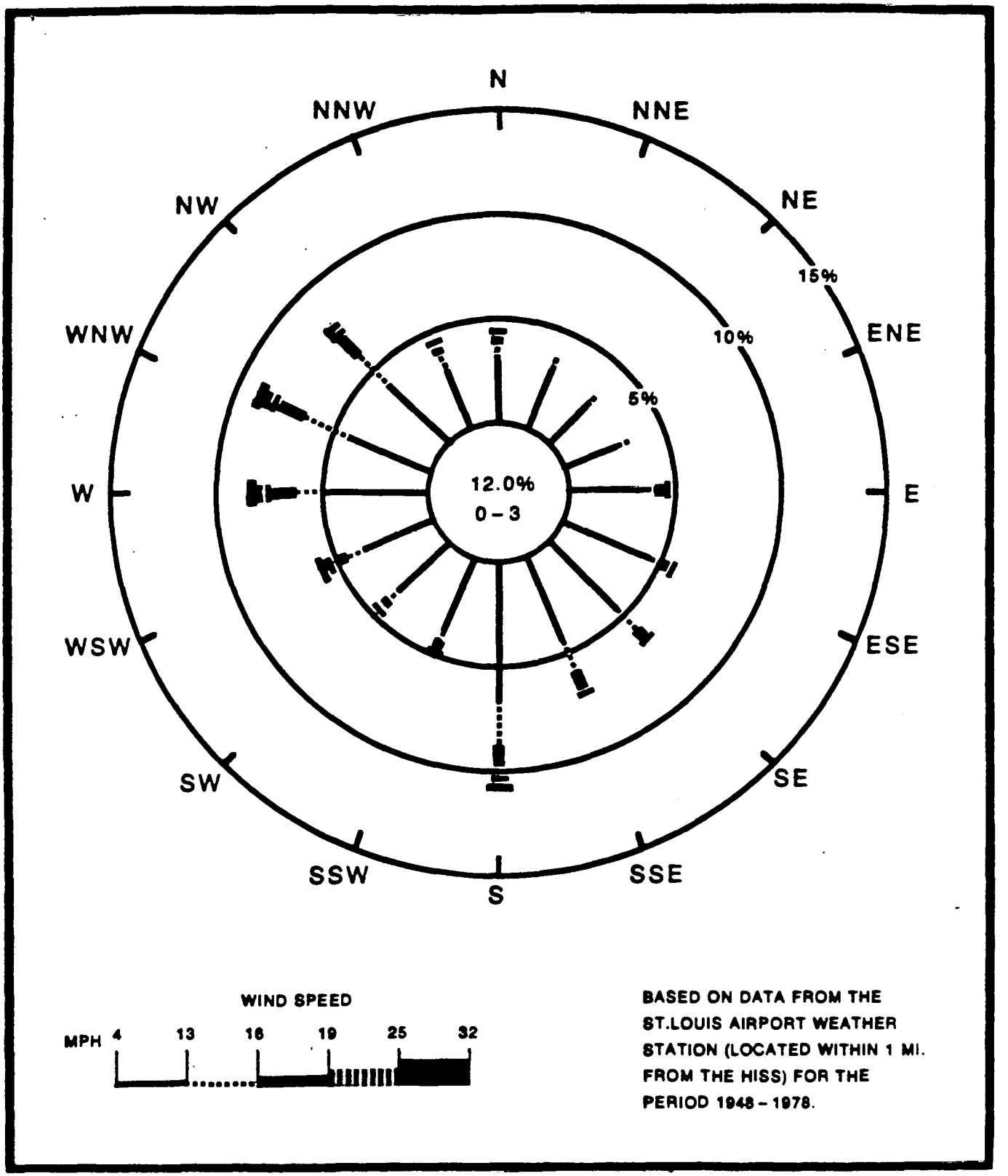


FIGURE 1-3 ANNUAL WIND ROSE FOR THE HISS, 1985

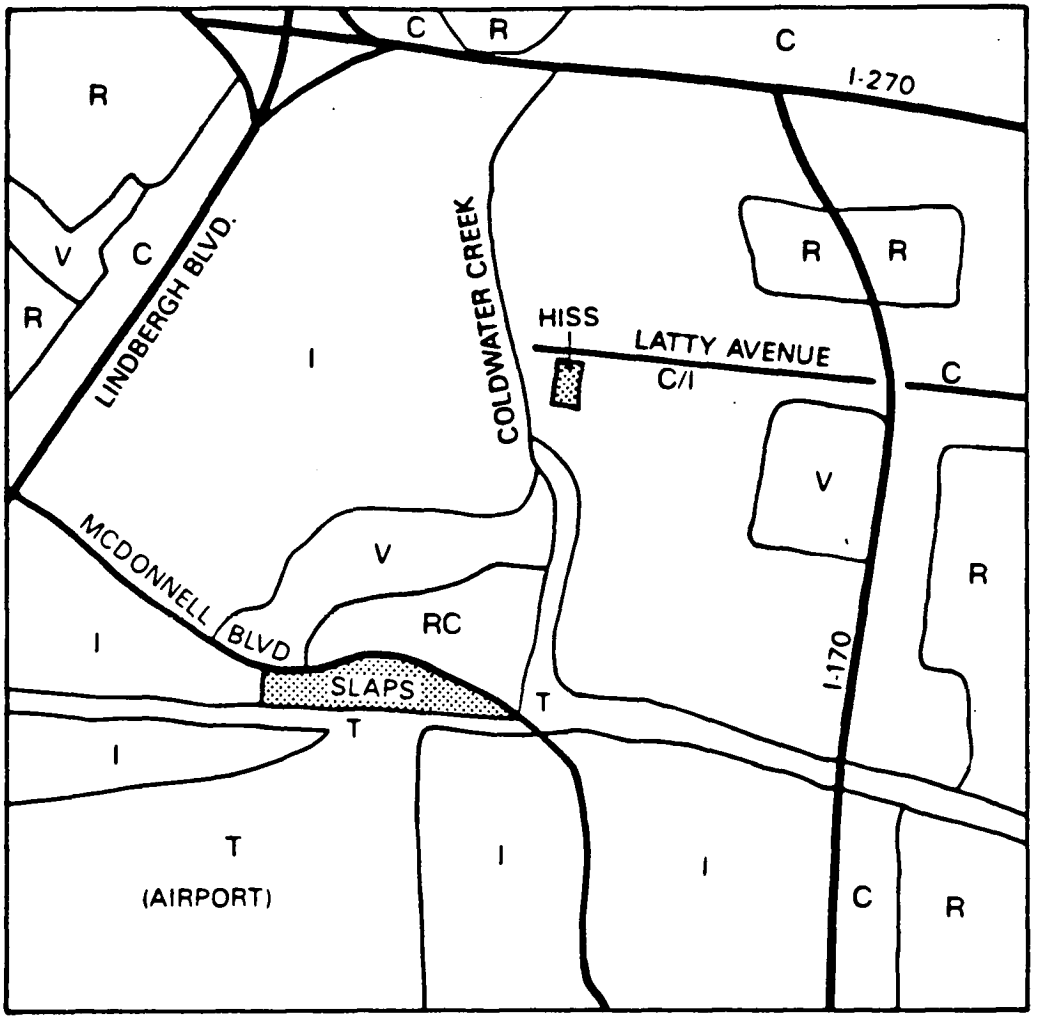
Berkeley and Hazelwood were 16,146 and 8,819, respectively (Ref. 6). There are no churches, schools, hospitals, municipal buildings, or other community facilities adjacent to the Hazelwood site or Latty Avenue.

As shown in Figure 1-4, land use in the vicinity is predominantly industrial, followed by commercial, transportation, vacant land, and residential property (Ref. 1).

1.2 SITE HISTORY

In early 1966, ore residues and uranium- and radium-bearing process wastes that had been stored at the St. Louis Airport Site (SLAPS) were purchased and moved to a storage site on Latty Avenue. These wastes had been generated by a St. Louis plant from 1942 through the late 1950s under contracts with the Atomic Energy Commission (AEC) and its predecessor, the Manhattan Engineer District (MED). Residues on the site at that time included 74,000 tons of Belgian Congo pitchblende raffinate containing approximately 13 tons of uranium; 32,500 tons of Colorado raffinate containing roughly 48 tons of uranium; and 8700 tons of leached barium sulfate containing about 7 tons of uranium. The Commercial Discount Corporation of Chicago, Illinois, purchased the residues in January 1967; much of the material was then dried and shipped to the Cotter Corporation facilities in Canon City, Colorado. The material remaining at the Latty Avenue site was sold to the Cotter Corporation in December 1969. From August through November 1970, Cotter Corporation dried some of the remaining residues at the site and shipped them to its mill in Canon City. In December 1970, an estimated 10,000 tons of Colorado raffinate and 8700 tons of leached barium sulfate remained at the Latty Avenue Site (Ref. 7).

In April 1974, the newly established Nuclear Regulatory Commission was informed by Cotter Corporation that the remaining Colorado raffinate had been shipped in mid-1973 to Canon City without drying and that the leached barium sulfate had been diluted with site soil



BASED ON AERIAL PHOTOGRAPHS, SITE VISITS AND USGS TOPOGRAPHIC MAP 1:24000 SCALE, FLORISSANT, MO (PHOTO REVISED 1982)

R RESIDENTIAL	C/I MIXED COMMERCIAL AND INDUSTRIAL
C COMMERCIAL	V VACANT
T TRANSPORTATION	RC RECREATIONAL
I INDUSTRIAL	

0 0.5 MILES

N

FIGURE 1-4 GENERALIZED LAND USES IN THE VICINITY OF THE HISS

and transported to a landfill area in St. Louis County. Reportedly, 30 to 45 cm (12 to 18 in.) of topsoil had been removed with the leached barium sulfate.

Before the present owner occupied the site, a radiological characterization was done by the Oak Ridge National Laboratory (ORNL). Thorium and radium contamination in excess of DOE guidelines was found in and around the buildings, and in the soil to depths of up to 45 cm (18 in). Consequently, in preparing the property for use, the owner demolished one building, excavated portions of the western half of the property, and paved certain areas in addition to erecting several new buildings. The material excavated during these activities [approximately 9880 m^3 (13,000 yd^3)] was piled on the eastern portion of the property.

In 1981, Oak Ridge Associated Universities (ORAU) characterized the pile and surveyed the northern and eastern boundaries of the property for radioactivity. Levels of contamination (principally thorium-230) similar to those on-site were found in both areas. As a followup to this survey, ORNL conducted a detailed radiological survey of the north and south shoulders of Latty Avenue for DOE in January and February 1984. Results indicated that contamination in excess of DOE guidelines was present along the road almost all the way to Hazelwood Boulevard. Properties adjacent to the HISS were also found to be contaminated.

As part of the research and development decontamination program authorized by Congress under the 1984 Energy and Water Appropriations Act, BNI is conducting remedial action at the site and at vicinity properties. The remedial action project at the HISS is divided into two phases. Phase I was conducted in 1984 and 1985 and consisted of radiological characterization and cleanup of the vicinity properties, and storage of the contaminated materials [an additional 10,260 m^3 (13,500 yd^3)] in the interim storage pile on the HISS. During Phase II, the HISS will be decontaminated, and it is planned that all contaminated materials will be removed to SLAPS (Figure 1-1) for long-term disposal (Ref. 7). Detailed

radiological characterization surveys of the HISS are scheduled for October and November 1986. These surveys will include both surface and subsurface investigations. In addition, it is expected that the radiological condition of the structures present on the western portion of the property will be determined as part of these surveys.

2.0 SUMMARY

During 1985, the environmental monitoring program at the HISS continued; air, water, and sediment samples were taken, and radon levels and external gamma rates were measured to determine compliance with applicable limits. These limits generally represent the concentrations of individual types of radioactive materials (radionuclides) in air or water that limit the radiation dose to the most highly exposed individual to 100 mrem/yr. The revised DOE Derived Concentration Guides for radioactive materials and the revised DOE radiation protection standard are provided in Appendix B (Ref. 8). A discussion of the revisions is also included in Appendix B. Radiation doses at the HISS during 1985 were calculated to permit a comparison to radiation protection standards.

Radon gas concentrations at all monitoring locations were less than the DOE guide. Annual average radon concentrations ranged from 10 to 23 percent of the DOE guide (Table 3-1). The measured value of background radon concentration in the vicinity of the HISS was 17 percent of the DOE guide. In 1984, the annual average radon concentration ranged from 10 to 74 percent of the DOE guide. Section 3.1 contains a discussion of radon concentrations at the HISS in 1985.

External dose rates measured at the HISS in 1985 ranged from 7 to 287 mrem per year (Table 3-2). These rates may be compared to the external exposure rate from naturally occurring background radiation in the vicinity of the HISS, which was measured at 99 mrem/yr. The maximum dose at the site boundary, assuming an occupancy factor of 2 h/wk, is 3.4 mrem/yr. External dose rates are discussed in Subsection 3.2. These rates are generally lower than those recorded in 1984 (Ref. 9).

In surface waters (Subsection 3.3.1) all measured concentrations of uranium, radium-226, and thorium-230 were a small fraction of the

Derived Concentration Guides for release off-site. The highest uranium level was 0.7 percent of the Derived Concentration Guide; for radium-226 it was 0.3 percent of the Guide, and for thorium-230 it was 1.7 percent of the Guide (Table 3-3). Average concentrations of uranium were lower than those measured in 1984, while those of radium-226 and thorium-230 were roughly equivalent to 1984 levels (Ref. 9).

In groundwater (Subsection 3.3.2) the highest annual average concentration of uranium was 12 percent of the Derived Concentration Guide (Table 3-4). For radium-226, the highest concentration was 3.6 percent of the Guide; the highest thorium-230 concentration was 1.8 percent of the Guide. Overall, concentrations of all three radionuclides were lower than those recorded in 1984 (Ref. 9).

In stream sediments (Section 3.4) the highest concentration of total uranium was 19 pCi/g; the highest radium-226 concentration was 4 pCi/g (Table 3-5). While there are no concentration guides for sediments, the radium and thorium concentrations may be compared with the DOE FUSRAP guidelines for cleanup of soils (Ref. 10). The radium concentrations are below the levels specified in these guidelines. Six of the eight sediment samples exhibited concentrations of thorium-230 below the level specified in the cleanup guidelines. At the two remaining sampling locations, the concentration was found to be 15 pCi/g and 300 pCi/g, respectively.

During 1985, releases of small amounts of radioactive materials from the HISS to the environment occurred. The rate of radon release was slightly enhanced as the result of disturbance of the soil during normal construction activities. Similarly, small concentrations of uranium, radium-226, and thorium-230 were present in rainwater runoff from the site during 1985. All such releases were below applicable guideline limits as determined by site and

vicinity monitoring data for radon and by measured concentrations of uranium, radium-226, and thorium-230 in waters leaving the site via natural drainage paths.

Calculations were made of radiological doses received by a maximally exposed individual. This individual is one who is assumed to remain adjacent to the site and who would, when all potential routes of exposure are considered, receive the greatest dose. Two exposure pathways were quantified: ingestion of contaminated surface or groundwater, and exposure to external gamma radiation. Ingestion of groundwater would result in a 50-yr dose commitment to the bone surface (the organ of the body receiving the greatest dose) of 70 mrem, or a 2-mrem contribution to the total body dose.

The maximum measured dose rate from radioactive materials at the HISS contributed 287 mrem/yr to the dose rate. This exposure rate would result in an annual dose of 3.4 mrem to the maximally exposed individual (Subsection 3.5.1). The total body dose to the maximally exposed individual would be 5.4 mrem. By comparison, exposure to the measured background would result in an annual dose of approximately 99 mrem/yr; the DOE radiation protection standard for exposure periods of greater than 5 years is 100 mrem/yr.

Results of the 1985 monitoring show that the HISS is in compliance with DOE Derived Concentration Guides and the radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of the 1985 environmental monitoring at the HISS (Ref. 11) and states the extent to which these results conform to the applicable DOE Derived Concentration Guides (DCGs) and radiation protection standard; a description is also given of the sampling, monitoring, and analytical procedures used. The DCGs in most cases specify the concentration of a radionuclide in air or water that would limit the dose to the most highly exposed individual to 100 mrem/yr. Radiation doses were calculated to determine hypothetical exposure levels, which were compared to this value. DOE radiation protection standards and DCGs for radionuclides of concern at HISS are included in Appendix B. Appendix B also contains a discussion of the revised radiation protection standards and associated DCGs. Both the units of measurement and the numerical values of the DCGs have changed from those used in previous years (Ref. 8).

Data are presented in summary tables by sample category. Summaries of data include minimum and maximum values recorded; number of data points collected; average value; and, where appropriate, percent of applicable Standard or DCG. The average values listed in the individual tables are the arithmetic average of the sum of individual results. Individual sources of error (e.g., analytical error or sampling error) were not estimated. The "less than" notation (<) is used to denote sample analysis results that are below the limit of sensitivity of the analytical method based on a statistical analysis of parameters. In computing the averages, where values are less than the limit of sensitivity of the analytical method, values are considered as being equal to the limit of sensitivity and the average value is reported without the notation "less than."

3.1 RADON GAS SAMPLING

Radon gas detectors were maintained at 8 locations on the site and along the site boundary at the HISS. These locations are shown in

Figure 3-1. One location is maintained some distance off-site to measure the background level. Sampling locations were selected on the basis of the potential for elevated radon releases. Detectors are spaced along the site boundary to ensure adequate detection capability under most atmospheric conditions.

The radon gas monitors are Terradex Type-F Track-Etch detectors. Detectors are obtained from the Terradex Corporation, placed at the sampling locations and collected by site personnel on a quarterly exchange, and then returned to Terradex for analysis.

Table 3-1 reports the measured concentrations of radon gas in the air at the HISS. Annual average concentrations ranged from 3×10^{-10} to 8×10^{-10} μCi/ml (0.3 to 0.7 pCi/l), with the highest annual average equal to 23 percent of the DOE guide of 3×10^{-9} μCi/ml (3 pCi/l). The measured annual average background was 5×10^{-10} uCi/ml (0.5 pCi/l) or 17 percent of the guide. The 1985 radon levels were lower than those measured in 1984, when averages ranged from 3×10^{-10} to 2.2×10^{-9} μCi/ml (0.3 to 2.2 pCi/l) (Ref. 9). Since radon concentrations have been measured at the HISS for only six quarters, it is not possible to draw meaningful trend charts. These will be included in future reports when more data are available.

3.2 EXTERNAL GAMMA DOSE RATES

External gamma dose rates were measured at 8 locations, all of which correspond to the radon (Terradex) detector locations shown in Figure 3-1. Detectors are located around the site boundary to ensure adequate measurement of exposure rates. The external gamma exposure rates are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs), exchanged quarterly. Each dosimeter contains five TLD chips, the responses of which are averaged. Analysis is performed by Eberline Analytical Corporation (EAC).

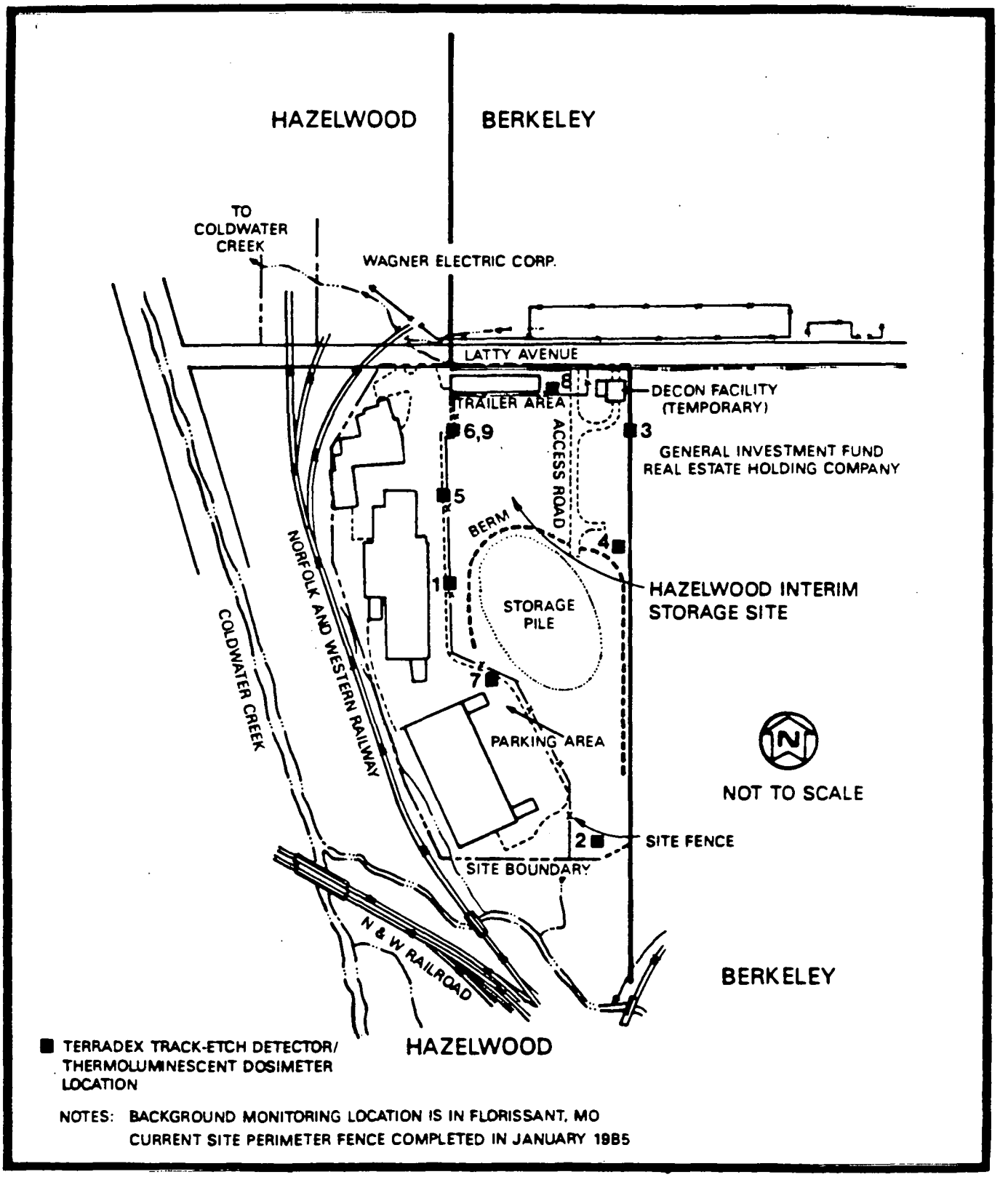


FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT THE HISS

TABLE 3-1

SUMMARY OF RADON-222 CONCENTRATIONS MEASURED AT THE HISS, 1985

Sampling Location[a]	Number of Samples	Concentrations ($n \times 10^9$) uCi/ml[b] Minimum	Maximum	Average	Percent of Standard[c] (Annual Average)
1	4	0.2	0.4	0.3	10
2	4	0.3	0.5	0.5	17
3	4	0.3	0.5	0.4	13
4	4	0.1	0.6	0.5	17
5	4	0.1	0.6	0.4	13
6	4	0.5	1.0	0.7	23
7	4	0.2	0.7	0.4	13
8	4	0.3	0.4	0.3	10
9[d]	4	0.2	0.9	0.5	17
Background[e]	4	0.3	0.5	0.5	17

[a]Sampling locations are shown in Figure 3-1.

[b]Multiply n (the listed concentration) by 10^9 to obtain uCi/ml.

[c]Based on a limit of 3×10^{-9} uCi/ml (3.0 pCi/l) for radon-222 in uncontrolled areas. Background has not been subtracted. See discussion in Appendix B.

[d]Location 9 is a quality control for Location 6.

[e]Located in Florissant, MO.

The results of external gamma monitoring are presented in Table 3-2. The measured background dose rate for the HISS area (99 mrem) has been subtracted from the measured dose rates in Table 3-2 to provide an estimate of the effect of the site on measured dose rates at the site boundary. The highest external dose rate was 287 mrem/yr at Location 6. This value is approximately three times the value of the measured background of 99 mrem/yr. Because the area adjacent to Location 6 is used as a parking lot, a 2-hour-per-week occupancy factor is appropriate. On this basis, the dose to an individual working on this property would be 3.4 mrem/yr.

Average external exposure rates measured in 1985 were lower than those in 1984. Trend charts will be provided when sufficient data have been collected to allow the plotting of meaningful graphs.

3.3 WATER SAMPLING

During 1985, sampling was performed to determine the concentrations of uranium, radium-226, and thorium-230 in surface water in the vicinity of the HISS and in groundwater at the site. The 8 surface water sampling locations and 11 groundwater sampling locations are shown in Figure 3-2.

3.3.1 Surface Water

Surface water samples were collected quarterly at sampling locations established on the basis of potential contaminant migration and discharge routes from the site. Sampling points were both upstream to establish background conditions and downstream to determine the effect of runoff from the site on surface waters in the vicinity.

Nominal 1-liter grab samples were collected to fill a 4-liter container. Samples were analyzed by EAC. The concentration of total uranium was determined by a fluorometric method. Radium-226 concentrations were determined by precipitating radium-226 as the sulfate, transferring the sulfate to a radon bubbler where the

TABLE 3-2

EXTERNAL GAMMA DOSE RATES AT THE HISS, 1985

Sampling Location[a]	Number of Samples	Units (Average Response in mrem/qtr) Minimum	Maximum	Average	Total[b] (mrem/yr)
1	4	2	27	15	58
2	4	12	27	22	87
3	4	0	19	6	25
4	4	8	27	21	83
5	4	20	48	35	141
6	4	56	93	72	287
7	4	9	33	22	89
8	4	0	3	2	7
9[c]	4	35	95	65	261
Background[d]	4	22	30	25	99

[a]Sampling locations are shown in Figure 3-1.

[b]Background has been subtracted. Total is calculated by summing the four measurements.

[c]Location 9 is a quality control for Location 6.

[d]Located in Florissant, MO.

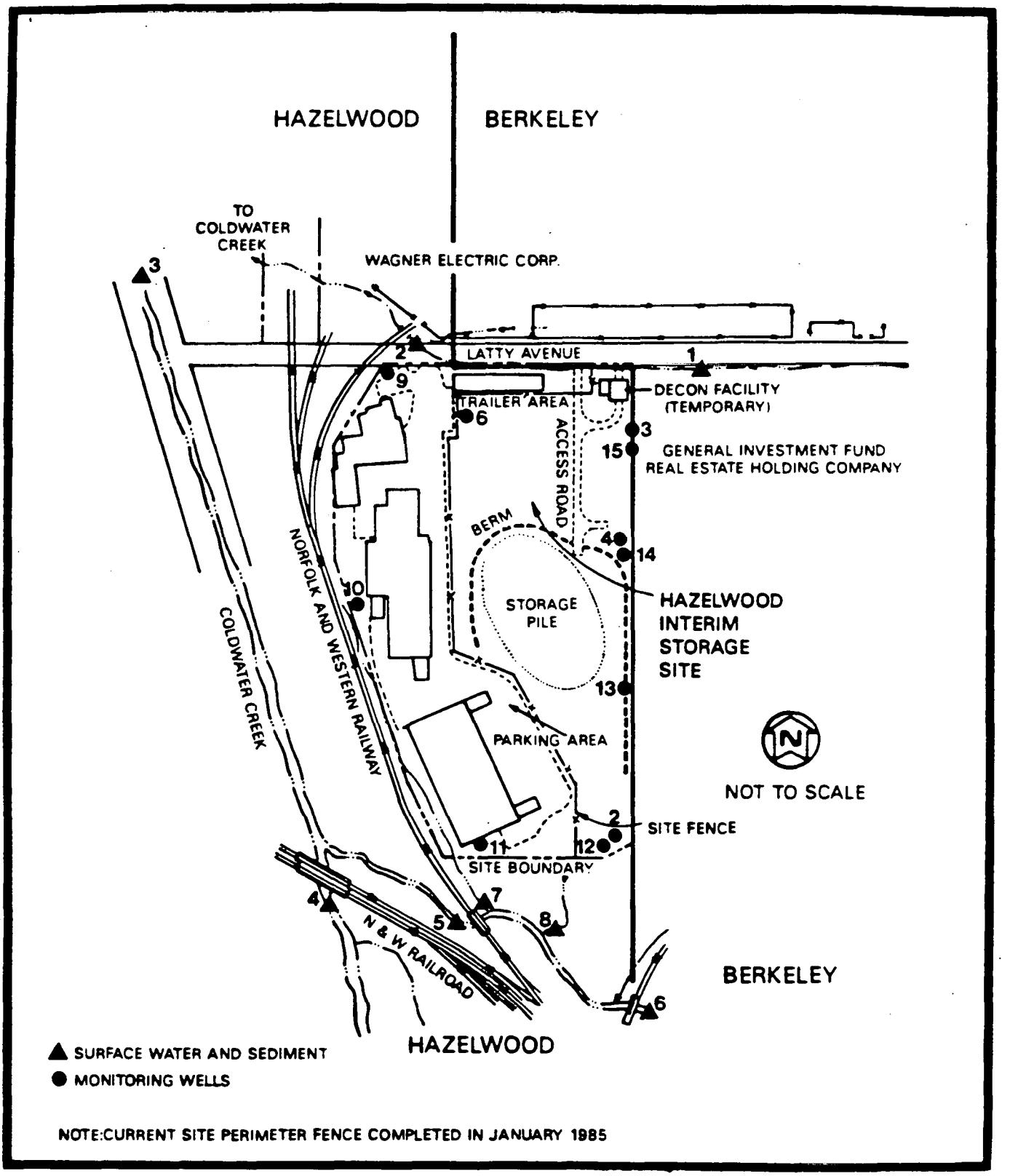


FIGURE 3-2 SURFACE WATER AND GROUNDWATER SAMPLING AT THE HISS

radon-222 daughter was allowed to come to equilibrium, and then counting the radon-222 by alpha spectrometry to determine the amount of parent radium-226 activity originally present. Thorium-230 was eluted in solution, electrodeposited on stainless steel discs, and counted by alpha spectrometry.

The results of analyses of surface water samples are presented in Table 3-3. Average total uranium concentrations ranged from 3×10^{-9} to 4.3×10^{-9} μCi/ml (3 to 4.3 pCi/l). Radium-226 levels ranged from 1×10^{-10} to 3×10^{-10} μCi/ml (0.1 to 0.3 pCi/l), and thorium-230 levels ranged from 1×10^{-10} to 5×10^{-9} μCi/ml (0.1 to 5.0 pCi/l). The highest annual average uranium concentration in surface water was 0.7 percent of the DCG (6×10^{-7} μCi/ml). The highest annual average radium-226 level was 0.3 percent of the DCG (1×10^{-7} μCi/ml). The highest annual average thorium-230 level was 1.7 percent of the DCG (3×10^{-7} μCi/ml).

Comparison of the concentrations of uranium, radium-226, and thorium-230 upstream and downstream of release points to surface waters indicates that the site does not adversely affect surface water quality.

Concentrations of total uranium have declined from 1984 when the averages ranged from 1 to 34 percent of the DCG. Concentrations of radium-226 and thorium-230 have remained roughly the same. Trend charts will be provided when sufficient data have been collected to permit the plotting of meaningful graphs.

3.3.2 Groundwater

During 1985, groundwater samples were collected quarterly from 11 monitoring wells established on the property boundary on the basis of available geohydrological data. Old Wells 2, 3, and 4 were sampled only during the first two quarters; they were removed from the program after sampling results were reviewed and shown to be similar to those from 1984. New Wells 13, 14, and 15 (in the same

TABLE 3-3

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN SURFACE WATER IN THE VICINITY OF THE HISS, 1985

Sampling Location[a]	Number of Samples	Concentration ($n \times 10^9$) uCi/ml[b] Minimum	Maximum	Average[c]	Percent of Standard[d] (Annual Average)
Total Uranium					
1[e]	3	<3.0	<3.0	3.0	0.5
2	4	<3.0	<3.0	3.0	0.5
3	4	<3.0	6.0	4.3	0.7
4	4	<3.0	8.0	4.3	0.7
5	4	<3.0	<3.0	3.0	0.5
6	4	<3.0	<3.0	3.0	0.5
7[e]	1	<3.0	<3.0	3.0	0.5
8[e]	2	<3.0	<3.0	3.0	0.5
Radium-226					
1[e]	3	<0.1	0.2	0.1	0.1
2	4	<0.1	0.3	0.2	0.2
3	4	<0.1	0.2	0.1	0.1
4	4	<0.1	0.3	0.2	0.2
5	4	<0.1	0.2	0.1	0.1
6	4	<0.1	0.2	0.2	0.2
7[e]	1	0.2	0.2	0.2	0.2
8[e]	2	0.1	0.5	0.3	0.3
Thorium-230					
1[e]	3	<0.1	0.1	0.1	0.03
2	4	<0.1	0.7	0.4	0.13
3	4	<0.1	13.0	3.3	1.10
4	4	<0.1	<0.5	0.2	0.07
5	4	<0.1	<0.2	0.2	0.07
6	4	<0.1	11.0	2.9	0.97
7[e]	1	5.0	5.0	5.0	1.67
8[e]	2	<0.2	7.0	3.6	1.20

[a]Locations shown in Figure 3-2; Locations 1, 4, and 6 are background.
[b]Multiply n (the listed concentration) by 10^9 to obtain uCi/ml.
[c]Where values are less than the limit of sensitivity of the analytical-method, values are considered as being equal to the limit of sensitivity, and the average value is reported without the notation "less than."
[d]The DCGs for uranium, radium-226, and thorium-230 in water are 6×10^{-7} uCi/ml (600 pCi/l), 1×10^{-7} uCi/ml (100 pCi/l), and 3×10^{-7} uCi/ml (300 pCi/l).
[e]Location 1 dry in the third quarter; Location 7 dry in the first three quarters; Location 8 dry in the second and third quarters.

locations as 2, 3, and 4) were added to the program during the third quarter. Old Well 6 was retained in the program to verify previous results. Nominal 1-liter grab samples were collected to fill a 4-liter container after the wells had been bailed dry or two casing volumes had been removed. Samples were analyzed by EAC for total uranium, dissolved radium-226, and dissolved thorium-230 using the methods applied to surface water analyses.

Results of the analyses of groundwater samples are presented in Table 3-4. The highest annual average total uranium concentration was 7.16×10^{-8} µCi/ml (71.6 pCi/l) or 12 percent of the DCG (6×10^{-7} µCi/ml). The highest annual average radium concentration was 1.1×10^{-9}uCi/ml (1.1 pCi/l) or 1.1 percent of the DCG (1×10^{-7} µCi/ml), and the highest annual average thorium concentration was 5.5×10^{-9} µCi/ml (5.5 pCi/l) or 1.8 percent of the DCG (3×10^{-7} µCi/ml).

Overall, there was a slight decrease in the concentrations of all three radionuclides as compared with those measured in 1984.

3.4 SEDIMENT SAMPLING

Sediment samples, consisting of composites weighing approximately 500 grams, were collected during the fourth quarter at the surface water sampling locations shown in Figure 3-2. The rationale for sampling location selection is stated in Subsection 3.3.1.

EAC analyzed the samples for uranium, radium-226, and thorium-230. The uranium concentration was obtained by summing the results from isotopic uranium analyses. Isotopic uranium and thorium-230 were determined by alpha spectrometry, where the uranium and thorium-230 are leached, extracted, and electroplated on metal substrates. Radium-226 concentrations were determined by radon emanation (described earlier).

There are no specific limits for uranium, radium, or thorium in sediments. However, cleanup of the HISS and its vicinity properties

TABLE 3-4

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN GROUNDWATER AT THE HISS, 1985

Sampling Location[a]	Number of Samples	Concentrations ($n \times 10^{9}$) uCi/ml[b] Minimum	Maximum	Average[c]	Percent of Standard[d] (Annual Average)
Total Uranium					
2	2	<3.0	<3.0	3.0	0.5
3	2	<3.0	8.7	5.9	1.0
4	2	8.7	17.3	13.0	2.2
6	4	56.7	93.4	71.6	12.0
9	4	<3.0	93.4	25.6	4.3
10	4	<3.0	3.3	3.1	0.5
11	4	<3.0	<3.0	3.0	0.5
12	4	<3.0	<3.0	3.0	0.5
13	2	<3.0	<3.0	3.0	0.5
14	2	<3.0	12.7	7.9	1.3
15	2	<3.0	<3.0	3.0	0.5
Radium-226					
2	2	0.4	0.5	0.5	1.5
3	2	0.2	1.0	0.6	2.0
4	2	<0.1	<0.1	0.1	0.3
6	4	0.3	1.6	0.8	2.6
9	4	0.2	0.6	0.4	1.3
10	4	<0.1	0.4	0.2	0.7
11	4	0.1	0.6	0.3	1.1
12	4	<0.1	0.5	0.4	1.2
13	2	<0.1	0.1	0.1	0.3
14	2	0.9	1.2	1.1	3.6
15	2	<0.1	0.4	0.3	0.8
Thorium-230					
2	2	0.6	<1.0	0.8	0.3
3	2	0.1	0.2	0.2	0.1
4	2	0.1	7.0	3.6	1.2
6	4	2.0	11.0	5.5	1.8
9	4	<0.1	<0.3	0.2	0.1
10	4	0.1	0.3	0.2	0.1
11	4	0.1	3.0	0.9	0.3
12	4	<0.1	1.1	0.4	0.1
13	2	<0.2	0.4	0.3	0.1
14	2	<0.2	0.2	0.2	0.1
15	2	0.4	0.6	0.5	0.2

[a]Sampling locations are shown in Figure 3-2. Wells 2, 3, and 4 removed from program after second quarter. Wells 13, 14, and 15 added to program in the third quarter.

Table 3-4 (continued)

[b]Multiply n (the listed concentration) by 10^9 to obtain μCi/ml.

[c]Where values are less than the limit of sensitivity of the analytical method, values are considered as being equal to the limit of sensitivity, and the average value is reported without the notation "less than."

[d]The DCGs for uranium in water is 6×10^{-7} μCi/ml (600 pCi/l). The DCG for radium-226 in water is 1×10^{-7} μCi/ml (100 pCi/l); the DCG for thorium-230 is 3×10^{-7} μCi/ml (300 pCi/l).

is being conducted in accordance with the DOE FUSRAP guidelines for radionuclides in soil. For comparative purposes, these guidelines are 5 pCi/g in the upper 15 cm (6 in.) and 15 pCi/g below 15 cm (6 in.) for radium and thorium (Ref. 10).

Results of the analyses, based on dry weight, are presented in Table 3-5. Average annual uranium concentrations ranged from 0.9 to 19 pCi/g, while radium-226 concentrations ranged from less than 0.1 to 4 pCi/g. Average annual thorium-230 concentrations ranged from 0.1 to 300 pCi/g.

Trends for 1984 through 1985 are difficult to determine since in 1984 sediment samples were obtained only at locations 7 and 8 and were analyzed only for thorium-230. Concentrations for thorium-230 during 1984 at stations 7 and 8 were 230 and 540 pCi/g, respectively (Ref. 9).

3.5 RADIOLOGICAL EXPOSURE

To assess the health effects of the radioactive materials stored at the HISS, the radiological exposure of a maximally exposed individual was evaluated. This individual is one who is assumed to remain adjacent to the site and who would, when all potential routes of exposure are considered, receive the greatest dose. An appraisal of potential pathways suggested that ingestion of water containing natural uranium, radium-226, and thorium-230, and external gamma irradiation were the principal exposure modes.

For each of the pathways considered at a given site, most organs in the body receive some radiological exposure. However, certain organs receive a higher exposure than others, depending on the method of internal deposition and the chemical characteristics of the radionuclides. These are called "critical organs" because the effect of the exposure is maximized in them.

Radium, uranium, and thorium taken into the body via ingestion tend to migrate and incorporate into the bone. This is the critical

TABLE 3-5

CONCENTRATIONS OF RADIUM-226, THORIUM-230, AND URANIUM IN SEDIMENT AT THE HISS, 1985

Sampling Location[a]	Number of Samples	Concentrations [pCi/g (dry)][b]					
		Radium-226	Thorium-230	Uranium-234	Uranium-235	Uranium-238	Total Uranium
1	1	1.8	3.8	0.7	0.04	0.7	1.4
2	1	<0.1	0.2	0.6	0.03	0.6	1.2
2	1	1.4	15.0	0.9	<0.05	1.0	1.95
4	1	1.0	1.2	0.6	0.06	0.6	1.3
5	1	1.4	2.8	0.4	<0.03	0.5	0.9
6	1	1.7	1.2	0.5	0.02	0.5	1.0
7	1	4.0	300.0	9.2	0.40	9.4	19.0
8	1	4.0	0.1	2.2	0.11	2.4	4.7

[a]Sampling locations shown in Figure 3-2. Locations 1, 4, and 6 are upstream of the site and are background locations.

[b]There are no specific limits for radium, thorium, or uranium, in sediment. However, decontamination of the HISS is being conducted in accordance with the DOE FUSRAP guidelines for radionuclides in soil. For comparative purposes, these guidelines are 5 pCi/g in the upper 15 cm (6 in.) and 15 pCi/g below 15 cm (6 in.) for radium and thorium (Ref. 9).

organ for this pathway. Establishing an internal dose to the bone by converting measured concentrations in water requires several assumptions. An intake rate must be postulated. For these calculations, the maximum water intake rate (730 ml of tap water per day) of Reference Man was used (Ref. 12). Radionuclide intakes were converted to internal doses to the bone using the methodology described in ICRP 26 and 30 (Refs. 13 and 14). All calculated doses are 50-yr dose commitments. The 50-yr dose commitment concept provides for the fact that an intake of a radionuclide with a long half-life (such as uranium and radium) may result in an internal exposure for many years.

Gamma radiation from external sources is assumed to irradiate the body uniformly. The total body is therefore the critical organ for external gamma exposure. Internal organs are assumed to be exposed to the same level as the entire body. Exposure to organs resulting from internal and external sources is additive.

Inhalation of radon and its radioactive daughters is also a pathway; however, accurate, quantitative determination of dose is not possible because of uncertainties concerning the distribution of exposure. In Section 3.1, measured radon concentrations are compared to the DOE guide, with the highest annual average equal to approximately 23 percent of the DOE guide.

3.5.1 Dose to Maximally Exposed Individual

To identify the individual in the vicinity of the HISS who would receive the highest dose from on-site radioactive materials, the combined dose from ingestion of water and exposure to external gamma radiation was calculated at various monitoring locations that could be accessible to the public. The cumulative doses from these pathways were then reviewed with regard to land use and occupancy factors for areas adjacent to the monitoring points. For the properties surrounding the HISS, the highest overall dose would be received by an individual west of the site. Since this is a commercial rather than a residential area, the doses were based on

an estimated 2-h/wk exposure period. To be conservative, the 730 ml/day water ingestion rate of Reference Man was used.

Exposure to external gamma radiation contributed most of the dose received by the maximally exposed individual. The average dose rate above background was 287 mrem/yr, as measured at monitoring Location 6 (Figure 3-1). The measured background dose rate is 99 mrem/yr. The occupancy factor for the property adjacent to Location 6 was estimated to be 2 h/wk, since the area is used only for parking. Exposure at this dose rate for 2 h/wk would result in an annual dose to the total body of approximately 3.4 mrem.

Well 6 (Figure 3-2) is the groundwater monitoring location nearest to external gamma monitoring Location 6. The annual average uranium, radium-226, and thorium-230 concentrations at Well 6 were 7.16×10^{-8}, 8×10^{-10}, and 5.5×10^{-9} uCi/ml (71.6, 0.8, and 5.5 pCi/l), respectively. Ingestion of this water would result in a 50-yr dose commitment of approximately 70 mrem to the critical organ (the bone surface). No attempt was made to separately quantify the contribution of materials on the HISS and natural background radionuclides. The above dose can be compared to the 490-mrem dose (based on occupational exposure) received by ingesting water containing a concentration of 600 pCi/l of uranium (the DOE DCG).

The 3.4-mrem dose from external gamma radiation (see Subsection 3.2) and the 70-mrem dose from ingestion are used to calculate the total dose. However, the 70-mrem ingestion dose is multiplied by the internal organ-to-whole-body weighting factor of 0.03 (Ref. 13). This addition results in a total dose of 5.4 mrem to the maximally exposed individual. The DOE radiation protection standard limits the total body dose to members of the general public to 100 mrem/yr for periods greater than 5 years.

3.5.2 Dose to the Population in the Vicinity of the HISS

The dose to the population represents the conceptual cumulative radiation dose to all residents within an 80-km (50-mi) radius of a

given site. This calculated dose includes contributions from all potential pathways. For the HISS these pathways are: direct exposure to gamma radiation, inhalation of radon gas, and ingestion of water containing radioactivity.

The contribution to the population dose made by gamma radiation from the radioactive materials present on-site is too small to be measured; gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the gamma dose rate at a distance of 0.9 m (3 ft) from the radioactive source were 10 times that allowable, the dose rate at a distance of 6.4 m (21 ft) from the source would be indistinguishable from naturally occurring background radiation.

Similarly, radon gas is known to dissipate rapidly as distance from the radon source increases (Ref. 15). Therefore, exposure from the low radon concentrations at the HISS does not contribute significantly to population dose.

On the basis of radionuclide concentrations measured in water leaving the HISS, it also appears that there is no predictable pathway by which ingestion of water could result in a significant dose to the population. As water migrates farther from the source, radionuclide concentrations are further reduced, thereby lowering potential doses to even less significant levels. Since the contributions to population dose via all three potential exposure pathways are inconsequential, calculation of dose to the population is not warranted. The cumulative dose to the population within an 80-km (50-mi) radius resulting from radioactive materials present at the HISS would be indistinguishable from the dose that the same population would receive from naturally occurring radioactive sources.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

In 1985, approximately 76 m^3 (100 yd^3) of contaminated soil was excavated from scattered areas of residual contamination along Latty Avenue. The excavated areas were subsequently backfilled, and the contaminated material placed in the HISS storage pile. The pile was covered with a reinforced polyethylene sheet secured to the ground. The pile will remain at the HISS until the property is decontaminated during Phase II remedial actions.

4.2 SPECIAL STUDIES

No special studies were undertaken at the HISS during 1985.

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APPENDIX A
QUALITY ASSURANCE

APPENDIX A
QUALITY ASSURANCE

A comprehensive quality assurance program was maintained to ensure that the data collected were representative of actual concentrations in the environment. First, environmental data were obtained to prevent reliance on only a few results, which might not be representative of the existing range of concentrations. Second, newly collected data were compared with both recent results and historical data for each location and each environmental medium to ensure that deviations from previous conditions were identified and evaluated. Third, samples at all locations were collected using published procedures to ensure consistency in sample collection. Fourth, each analytical laboratory verified the quality of the data by conducting a continuing program of analytical quality control, participating in interlaboratory crosschecks, and performing replicate analyses, and splitting samples with other recognized laboratories. Fifth, chain of custody procedures were implemented to maintain traceability of samples and corresponding analytical results. This program ensures that the monitoring data can be used to evaluate accurately the environmental impacts from site operations.

The majority of the routine radioanalyses for the FUSRAP Environmental Monitoring Program were performed under subcontract by the Eberline Analytical Corporation, Albuquerque, New Mexico. This laboratory maintained an internal quality assurance program that involved routine calibration of counting instruments, source and background counts, routine yield determinations of radiochemical procedures, and replicate analyses to check precision. The accuracy of radionuclide determination was ensured through the use of standards traceable to the National Bureau of Standards, when available. The laboratory also participated in the Environmental Protection Agency's (EPA) Laboratory Intercomparison Studies Program. In this program, samples of different environmental media (water, milk, air filters, soil, foodstuffs, and tissue ash) containing one or more radionuclides in known amounts were prepared

and distributed to the participating laboratories. After the samples were analyzed, the results were forwarded to EPA for comparison with known values and with the results from other laboratories. This program enabled the laboratory to regularly evaluate the accuracy of its analyses and take corrective action if needed.

Interlaboratory comparison of the TLD results was provided by participation in the International Environmental Dosimeter Project sponsored jointly by the Department of Energy, the Nuclear Regulatory Commission, and the EPA.

To ensure the accuracy of dose calculations, all computed doses were double-checked by the originator and by an independent third party who also checked all input data and assumptions used in the calculations.

APPENDIX B
ENVIRONMENTAL STANDARDS

APPENDIX B
ENVIRONMENTAL STANDARDS

The radiation protection standards and associated Derived Concentration Guides (DCG) applicable to Department of Energy (DOE) installations have been modified (Ref. 8).

The DOE long-term radiation protection standard has been reduced from 500 mrem/yr to 100 mrem/yr. In conjunction with this reduction, evaluation of exposure pathways and resulting dose calculations are based on realistic assumptions. Realistic assumptions may include the use of occupancy factors in determining dose due to external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely represents actual exposure conditions rather than maximum values as applicable; and using average consumption rates of food and water per individual rather than maximums. Utilization of realistic assumptions will result in lower calculated doses than previous years. However, these doses will more accurately reflect the exposure potential from site activities.

The associated DCGs, which provide limits for the maximum permissible radioactivity in various environmental media, have also been revised. The new DCGs reflect changes to the radiation protection standard and new uptake models. On a case-by-case basis, the DCG for a given radionuclide may have increased, decreased, or remained unchanged. The DCGs for the common radionuclides at the HISS are presented in Table B-1. For comparative purposes, the old and revised DCGs are presented. Conversion factors for the new reporting units are provided in Table B-2.

TABLE B-1

RADIATION PROTECTION STANDARD[a] AND
RADIOACTIVITY CONCENTRATION GUIDES FOR THE HISS

Radionuclide	Transport Medium	Previous Guide (Uncontrolled Areas)	New Guide
Uranium-Natural	Water	600 pCi/l	Unchanged[b]
Radium-226	Water	30 pCi/l	1×10^{-7} uCi/ml (100 pCi/l)
Radon-222	Air	3 pCi/l	Unchanged[b]
Thorium-230	Water	2,000 pCi/l	3×10^{-7} uCi/ml (300 pCi/l)

[a]The radiation protection standard was changed from 500 mrem/yr to 100 mrem/yr.

[b]The values are the same as for previous years, but are reported in different units.

TABLE B-2

CONVERSION FACTORS

1 yr	=	8760 h
1 liter	=	1000 ml
1 mrem	=	1000 uR
1 mrem/yr	=	11 uR/hr (assuming 8760 hours of exposure per year)
1 uCi	=	1,000,000 pCi
1 pCi	=	0.000001 uCi
1 pCi/l	=	10^{-9} uCi/ml
1 pCi/l	=	0.000000001 uCi/ml
1 uCi/ml	=	1,000,000,000 pCi/l
10^{-6}	=	0.000001
10^{-7}	=	0.0000001
10^{-8}	=	0.00000001
10^{-9}	=	0.000000001
10^{-10}	=	0.0000000001
7×10^{-10}	=	0.0000000007

APPENDIX C
ABBREVIATIONS

APPENDIX C
ABBREVIATIONS

cm	centimeter
cm/sec	centimeters per second
ft	foot
g	gram
gal	gallon
h	hour
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
m	meter
m^3	cubic meters
mg	milligram
mg/l	milligrams per liter
mi	mile
ml	milliliter
mph	miles per hour
mrem	millirem
mrem/qtr	millirem per quarter
mrem/yr	millirem per year
m.s.l.	mean sea level
uCi/ml	microcuries per milliliter
ug/l	micrograms per liter
uR/h	microroentgens per hour
pCi	picocurie
pCi/g	picocuries per gram
pCi/l	picocuries per liter
wk	week
yd^3	cubic yards
yr	year

APPENDIX D

DISTRIBUTION LIST FOR HAZELWOOD INTERIM STORAGE SITE ANNUAL SITE ENVIRONMENTAL MONITORING REPORT

APPENDIX D

DISTRIBUTION LIST FOR HAZELWOOD INTERIM STORAGE SITE ANNUAL SITE ENVIRONMENTAL MONITORING REPORT

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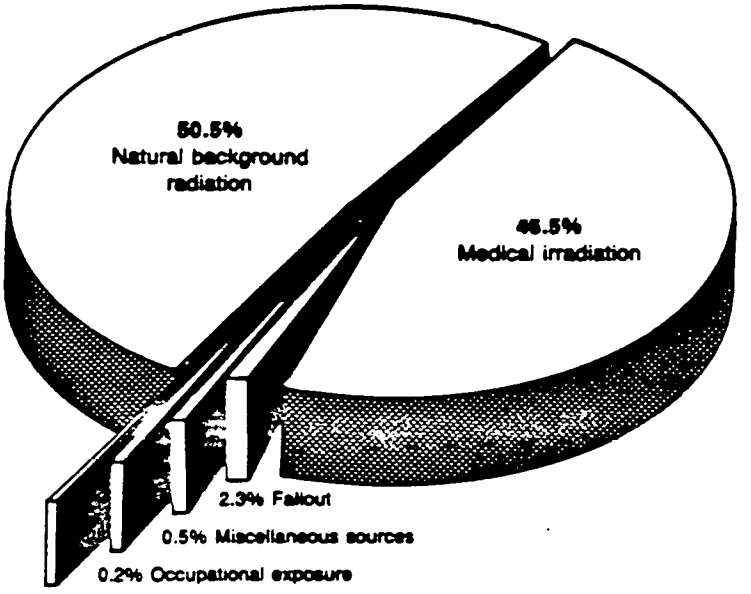
Radiation in the Environment

Radiation is a natural part of our environment. When our planet was formed, radiation was present—and radiation surrounds it still. Natural radiation showers down from the distant reaches of the cosmos and continuously radiates from the rocks, soil, and water on the Earth itself.



Source: National Academy of Sciences, 1980; National Council of Radiation Protection and Measurement

During the last century, mankind has discovered radiation, how to use it, and how to control it. As a result, some manmade radiation has been added to the natural amounts present in our environment.

Many materials—both natural and manmade—that we come in contact with in our everyday lives are radioactive. These materials are composed of atoms that are unstable. The unstable atoms release particles or waves as they change into more stable forms. These particles and waves are collectively referred to as *radiation*, and a quantity of the unstable atoms is referred to as *radioactivity*.

Types of Ionizing Radiation

Radiation that has enough energy to disturb the electrical balance in the atoms of substances it passes through is called *ionizing radiation*. There are three basic forms of ionizing radiation.

Alpha

Alpha particles are the largest and slowest moving type of radiation. They are easily stopped by a sheet of paper or the skin. Alpha particles can only move through the air a few inches before being stopped by air molecules. However, alpha radiation is dangerous to sensitive tissue inside the body.

Beta

Beta particles are much smaller and faster moving than alpha particles. Beta particles pass through paper and can travel in the air for about 10 feet. However, they may be stopped by thin shielding such as a sheet of aluminum foil.

Gamma

Gamma radiation is a type of electromagnetic wave that travels at the speed of light. It takes a thick wall of steel, lead, or concrete to stop gamma rays. X rays and cosmic rays are similar to gamma radiation. X rays are produced by manmade devices; cosmic rays reach Earth from outer space.

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Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980. Committee on the Biological Effects of Ionizing Radiations. National Academy Press, 1984.

Radiation Exposure from Consumer Products and Miscellaneous Sources: Report Number 56. National Council on Radiation Protection and Measurements, 1977.

Radiation in Medicine and Industry. A.P. Jacobson and G.P. Sakolosky, 1980.

Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978.

Units of Measure

Radiation can be measured in a variety of ways. Typically, units of measure show either the total amount of radioactivity present in a substance, or the level of radiation being given off.

The radioactivity of a substance is measured in terms of the number of transformations (changes into more stable forms) per unit of time. The *curie* is the standard unit for this measurement and is based on the amount of radioactivity contained in 1 gram of radium. Numerically, 1 curie is 37 billion transformations per second. The amounts of radioactivity that people normally work with are in the millicurie (one-thousandth of a curie) or microcurie (one-millionth of a curie) range. Quantities of radioactivity in the environment are in the picocurie, or pCi (one-trillionth of a curie) range.

Levels of radiation are measured in various units. The level of gamma radiation in the air is measured by the *roentgen*. This is a relatively large unit, so measurements are often calculated in milliroentgens. Radiation absorbed by humans is measured in either *rad* or *rem*. The rem is the most descriptive because it measures the ability of the specific type of radiation to do damage to biological tissue. Again, typical measurements will often be in the millirem, or mrem (one-thousandth of a rem) range. On the average, people receive about 180 mrem of radiation a year. Most of this radiation is from natural radiation and medical exposure.

RADIATION IN THE ENVIRONMENT

Cosmic Radiation

Cosmic radiation is high-energy gamma radiation that originates in outer space and filters through our atmosphere.

Sea Level.....26 mrem/year
(add one for each additional 100 feet in elevation)
Atlanta, GA (1,050 feet).....37 mrem/year
Denver, CO (5,300 feet).....79 mrem/year
Minneapolis, MN (815 feet)...34 mrem/year
Salt Lake City, UT (4,400 feet)..70 mrem/year
Spokane, WA (1,890 feet).....45 mrem/year

Terrestrial Radiation

Terrestrial sources are naturally radioactive elements in the soil and water such as thorium, radium, uranium, and carbon.

United States (average).....26 mrem/year
Denver, Colorado.....90 mrem/year
Nile Delta, Egypt.....350 mrem/year
Paris, France.....350 mrem/year
Coast of Kerala, India.....400 mrem/year
McAlpe, Brazil.....2,558 mrem/year
Pocos de Caldas, Brazil...7,000 mrem/year

Buildings

Based on occupancy 75 percent of the time.

Wood House.....35 mrem/year
Brick House.....45 mrem/year
Concrete House.....45 mrem/year
Stone House.....50 mrem/year

Specific Buildings

U.S. Capitol Building.....85 mrem/year
Base of Statue of Liberty....325 mrem/year
Grand Central Station.....525 mrem/year
The Vatican.....800 mrem/year

Radon

Radon levels in buildings vary, depending on geographic location, from 0.1 to 200 pCi/liter.

Proposed Radon Level.....1.5 pCi/liter
Occupational Working Limit...100.0 pCi/liter

The numbers given here are approximate or represent an average since samples vary.

mrem = millirem

pCi = picocurie

Foods

Food contributes an average of 20 mrem/year, mostly from carbon-14, hydrogen-3, potassium-40, radium-226, and thorium-232.

Beer.....390 pCi/liter
Domestic Tap Water.....20 pCi/liter
Milk.....1,400 pCi/liter
Salad Oil.....4,900 pCi/liter
Whiskey.....1,200 pCi/liter

Brazil Nuts.....14 pCi/g
Flour.....0.14 pCi/g
Peanuts and Peanut Butter.....0.12 pCi/g
Tea.....0.40 pCi/g

Medical Treatment

The exposures from medical diagnosis vary widely according to the required procedure, the equipment and film used for x rays, and the skill of the operator.

Chest X Ray.....20 mrem
Dental X Ray, Whole Mouth.....900 mrem

International Nuclear Weapons Test Fallout

Average for a U.S. citizen.....1 mrem/year

Consumer Goods

Cigarettes (2 packs/day)...8,000 mrem/year (Polonium-210)
Color Television.....1 mrem/year
Gas Lantern Mantle.....3 mrem/hour (thorium-232)
Highways.....4 mrem/year
Jet Airplane Travel/1,500 miles.....1 mrem (cosmic)
Natural Gas Stove.....6-9 mrem/year (radon-222)
Phosphate Fertilizers*.....4 mrem/year
Porcelain Dentures.....1,500 mrem/year (uranium salts)
Radioluminescent Clock.....9 mrem/year (radium-226)
Smoke Detector.....0.2 mrem/year (americium-241)

* Natural Radioactivity in Florida Phosphate Fertilizers (in pCi/gram)

Material	Ra-226	U-238	Th-230	Th-232
Normal Superphosphate	21.3	20.1	18.9	0.6
Concentrated Superphosphate	21.0	58.0	48.0	1.3
Gypsum	33.0	6.0	13.0	0.3