1165

DR-0426-X

DOE/OR/20722-7
(DE84015853)

Surplus Facilities Management Program (SFMP)
Contract No. DE-AC05-81OR20722

**RADIOLOGICAL SURVEY REPORT
FOR THE WELDON SPRING
RAFFINATE PITS SITE**

Weldon Spring, Missouri

Bechtel National, Inc.
Advanced Technology Division

August 1984

MASTER

Technical Information Center
Office of Scientific and Technical Information
U.S. Department of Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A03
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

RADIOLOGICAL SURVEY REPORT
FOR THE
WELDON SPRING RAFFINATE PITS SITE

AUGUST 1984

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.
Advanced Technology Division
Oak Ridge, Tennessee

Bechtel Job No. 14501

MASTER

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

The Weldon Spring Site (WSS) is a U.S. Department of Energy (DOE) surplus facility comprising the Raffinate Pits facility, the Quarry, and potentially contaminated vicinity properties. Radiological characterization of the WSS will be conducted in three phases: the Raffinate Pits facility, Quarry, and the vicinity properties. Bechtel National, Inc. (BNI) and its radiological support subcontractor, Eberline Instrument Corporation (EIC), conducted a radiological characterization survey of the Raffinate Pits during 1982 and 1983 in support of on-site construction work and a technical evaluation of site geology. The survey consisted of direct beta-gamma surface readings, near-surface gamma readings, exposure level measurements, and gamma-logs of boreholes. Soil samples were also collected from the surface, shallow boreholes, and trenches on the site.

This report describes the radiological characterization of the Raffinate Pits facility, the procedures used to conduct the survey, the survey results, and their significance.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

	<u>Page</u>
1.0 Introduction	1
2.0 Site Background and Description	6
2.1 Summary of Site History	6
2.2 Description of the Raffinate Pits	7
3.0 Survey Procedures	10
3.1 Field Measurements	10
3.2 Sample Collection and Analysis	12
4.0 Survey Results	13
4.1 Direct Measurements	13
4.2 Sample Analysis	16
5.0 Summary and Significance of Findings	32
References	33

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Weldon Spring Site (WSS) Area Map	2
1-2	WSS Vicinity Map	3
1-3	WSS Raffinate Pit Area	4
4-1	Results of Direct Gamma Measurements at the WSRP Site	14
4-2	Exposure Rates ($\mu\text{R/h}$) at the WSRP Site	15
4-3	Location of Gamma-Logged Boreholes at the WSRP Site	19
4-4	Location of Surface Soil Samples at the WSRP Site	25
4-5	Location of Surface Soil Samples Exceeding Uranium-238, Radium-226, and Thorium-232 Guidelines at the WSRP Site	26
4-6	Location of Trench Soil Samples at the WSRP Site	30

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
2-1	Surface Area, Volume, and Contents of the Weldon Spring Raffinate Pits	8
4-1	Gamma Log of Shallow Boreholes at the WSRP Site	17
4-2	Gamma Log of Geotechnical Boreholes at the WSRP Site	18
4-3	Residual Contamination Guidelines for Formerly Utilized Sites and Remote Surplus Facilities Management Program Sites	20
4-4	Radionuclide Concentrations in Surface Soil Samples from the WSRP Site	21
4-5	Background Radiation Levels and Nuclide Concentrations in Surface Soil Samples in the State of Missouri	24
4-6	Radionuclide Concentrations in Sidewall Trench Samples from the WSRP Site	28
4-7	Radionuclide Contents of the Weldon Spring Raffinate Pits	31

ABBREVIATIONS

cm	centimeter
cpm	counts per minute
dis/s	disintegrations per second
ft	foot
g	gram
ha	hectare
in.	inch
kg	kilogram
km	kilometer
lb	pound
m	meter
m ²	square meter
m ³	cubic meter
mi	mile
μR/h	microroentgens per hour
pCi/g	picocuries per gram
t	tonne
yd ³	cubic yards

1.0 INTRODUCTION

The Weldon Spring Site (WSS) is a U.S. Department of Energy (DOE) surplus facility located in St. Charles County, Missouri approximately 48 km (30 mi) west of the city of St. Louis. The site comprises two separate facilities approximately 6.4 km (4 mi) apart -- the 21-ha (52-acre) Raffinate Pits facility and the 3.4-ha (9-acre) Quarry. The Weldon Spring Raffinate Pits (WSRP) facility is located approximately 22 km (14 mi) southwest of the city of St. Charles and is accessed from Missouri State Route 94. The site is approximately 3.2 km (2 mi) southwest of the junction of Route 94 and Route 40. Both the Raffinate Pits and the Quarry are presently used for the storage of low-level radioactive residues, waste materials, and contaminated rubble. The general location of the two properties is illustrated in Figure 1-1. DOE is also responsible for vicinity properties near the Raffinate Pits and Quarry that may have become contaminated as a result of operations at the facilities.

The WSRP facility includes four pits covering a total of approximately 11 ha (27 acres). As shown in Figure 1-2, the site is bordered on all sides by U.S. Army-owned land. The western half of the site is bounded by a large Army Reserve and National Guard training area, and the eastern half is bounded by the Army-owned Weldon Spring Chemical Plant, inoperative since 1966. To the north beyond the Army-controlled area is the August A. Busch Wildlife Area, a large public park which is administered by the Missouri Department of Conservation. The Weldon Spring Wildlife Area, also administered by the Missouri Department of Conservation, lies to the south. Access to the WSRP site is controlled by a 2-m-high (7-ft-high) fence enclosing the DOE property. Each of the pits is also encircled by a smaller interior fence. Figure 1-3 shows the four pits, their relative size and location, and other site features.

FIGURE 1-1 WELDON SPRING SITE (WSS) AREA MAP

FIGURE 1-2 WSS VICINITY MAP

FIGURE 1-3 WSS RAFFINATE PIT AREA

Since October 1981, both the WSRP site and the Quarry have been maintained by Bechtel National, Inc. (BNI), which was chosen by DOE as the Project Management Contractor (PMC) for the site. As part of its duties as PMC, BNI maintains security, performs maintenance as required, and carries out an environmental monitoring program through close cooperation with its radiological support subcontractor, Eberline Instrument Corporation (EIC). The radiological survey presented in this document was conducted in support of repair work on Pit 4 and other site construction activities as well as investigations of site geology. It was the first phase of the three-phase radiological characterization of the WSS. Surveys of the Quarry and the vicinity properties will follow.

2.0 SITE BACKGROUND AND DESCRIPTION

A brief history of the Raffinate Pits and a description of their present condition are provided in this section.

2.1 SUMMARY OF SITE HISTORY

In 1956 the Atomic Energy Commission (AEC), predecessor to DOE, acquired about 89 ha (220 acres) of the original Weldon Spring Ordnance Works Plant from the Department of the Army (DOA) to develop a uranium feed materials plant. With the closing of the Mallinckrodt Chemical Works' Destrehan Street (St. Louis, Missouri) uranium ore processing facility in 1957, all operations at this facility were transferred to the AEC's new facility, called the Weldon Spring Chemical Plant. Mallinckrodt, Inc. operated this facility for the AEC from 1957 until operations ceased in 1966.

The Chemical Plant was an integrated facility which converted uranium ore concentrates and recycled scrap to pure uranium trioxide, intermediate compounds, and uranium metal. An average of approximately 14,500 t (16,000 tons) of uranium materials were processed at this plant annually. A relatively small amount of thorium was also processed. The wastes generated during operations were stored in the four raffinate pits located adjacent to the plant. The residues discharged to the pits consisted of raffinates from uranium refining operations, washed magnesium fluoride slag residues from uranium metal production, and raffinate solids from the processing of thorium recycle materials.

The raffinates were neutralized with lime and pumped to the pits as a slurry. The solids, principally acid-insoluble compounds in the feed materials (chiefly silica), settled in the pits. The supernatant liquid overflowed to the Chemical Plant process sewer, where it was mixed with storm water and sewage treatment

effluent. It was then discharged from the sewer outfall into a small stream that flows approximately 2.4 km (1.5 mi) to the Missouri River.

In 1966 the AEC shut down the Chemical Plant and in 1967 returned the facility to the DOA for planned use as a defoliant production plant. The Army started removing equipment and decontaminating the site buildings in 1968. About 4,600 m³ (6,000 yd³) of contaminated material were hauled to the Quarry. An undetermined amount of contaminated material, consisting of piping, ducting, drums, and other scrap material, was also dumped in Raffinate Pit 4. The defoliant project was cancelled in 1969 before any herbicide was produced. The DOA retained the responsibility for the land and the facilities referred to as the Chemical Plant. The 21-ha (52-acre) tract encompassing the four raffinate pits was transferred back to the AEC. The 3.4-ha (9-acre) Quarry also remained under the control of the AEC. The AEC, and later DOE, contracted with National Lead Company of Ohio (NLO) to periodically visit the Raffinate Pits and Quarry to maintain the sites, provide security, and perform environmental monitoring. These responsibilities were assumed by BNI in October 1981.

2.2 DESCRIPTION OF THE RAFFINATE PITS

The surface area, volume, and contents of the Raffinate Pits are summarized in Table 2-1.

The pit drains and all transfer lines from the pits to the Chemical Plant storm sewer have been sealed (Ref. 1). Water covers the pit residues for most of the year, depending upon temperature and precipitation. In the summer months, the surface water in Pits 1 and 2 may evaporate, leaving a dry and cracked surface. The level of water in Pits 3 and 4 fluctuates, but some surface water is always present. Water has never overflowed from any of the pits except for a designed overflow from Pit 3 to Pit 4 during periods of heavy rainfall.

TABLE 2-1
SURFACE AREA, VOLUME, AND CONTENTS
OF THE WELDON SPRING RAFFINATE PITS

Pit	Constructed	Surface Area (acres)	Total Pit Volume (yd ³)	Total Waste Volume (yd ³)	Percent Filled
1	1958	1.2	18,500	17,400	94
2	1958	1.2	18,500	17,400	94
3	1959	8.4	166,700	129,600	78
4	1964	<u>15.0</u>	<u>444,400</u>	<u>55,600</u>	12
	TOTAL	<u>25.8</u>	<u>648,100</u>	<u>220,000</u>	

In 1982 a portion of the dike around Pit 4 was repaired to stabilize a shallow circular arc slide. During this activity, site roads were repaired and a temporary decontamination facility was constructed. In addition, utilities (power, potable water, and telephone) were installed to support construction and monitoring activities. The radiological survey presented in this document was undertaken in support of these construction activities and a technical evaluation of site geology.

3.0 SURVEY PROCEDURES

The radiological survey presented here was conducted by BNI/EIC in June 1982 with follow-up work in the winter of 1982-83. The survey grid system corresponded with the AEC grid which is $28^{\circ}-19'-33''$ east of true north. The grid was established on 30-m (100-ft) intervals which were further reduced during the 1982-83 survey to (6-m) (20-ft) or 1.5-m (5-ft) intervals over areas of elevated readings.

3.1 FIELD MEASUREMENTS

Gamma measurements were made near surface (30 cm or 1 ft) and 1 m from the ground surface. Near-surface measurements were made using a 5-cm x 5-cm (2-in. x 2-in.) sodium-iodide (NaI) detector (EIC Model SPA-3).

The detector was mounted in a probe assembly surrounded with a conical lead shield to reduce the gamma intensity through the sides, thus providing a downward directional response. The detector was coupled with an EIC PRS-1 ratemeter/scaler. The average background reading was 6000 cpm.

Beta-gamma dose rate measurements were made at the ground surface using a thin-window (GM) probe (EIC Model HP-210) coupled with a ratemeter/scaler (EIC Model PRS-1). The average background in the landfill area using an HP-210 probe was 50 cpm.

Gamma exposure rates at 1 m (3 ft) above the ground were also made using an EIC Model SPA-3. Measurements were taken in the center of the grid points at 30-m (100-ft) intervals. A pressurized ion chamber (PIC) was also used to make a series of measurements to obtain the calibration factor used to estimate the gamma exposure rate from NaI detector readings in $\mu\text{R/h}$. The PIC response is proportional to exposure in roentgens. The average background using the PIC in the Weldon Spring area was $9 \mu\text{R/h}$.

Initial gamma measurements were made on the grid points at 30-m (100-ft) intervals. Walkover surface scans were also conducted. Locations of elevated radiations were noted and additional measurements were taken as necessary at 6-m (20-ft) intervals to define more precisely the boundaries of contaminated surface soil.

Further surveys were conducted following construction activities on site. Beta-gamma measurements were made at 6-m (20-ft) intervals in areas previously identified and at 1.5-m (5-ft) intervals where elevated readings were indicated. Gamma exposure rates were obtained at 45 of the 64 center grid points.

During December gamma scans were performed and the radiation readings logged in 12 shallow boreholes. The holes were 15 cm (6 in.) in diameter and 122 cm (48 in.) deep. The exceptions are holes W99,000 N50,600 and W98,800, N50,600 which were hand augered to a depth of 91 cm (36 in.). Timed gamma measurements were made at 15-cm (6-in.) vertical intervals.

In January and February 1983, an additional 16 boreholes were gamma-logged. These boreholes were drilled in support of the geotechnical activities on site. The boreholes were 15-cm (6-in.) diameter holes cased with 10-cm (4-in.) schedule 40 PVC or 20-cm (8-in.) diameter holes cased with 7-cm (3-in.) schedule 40 PVC. These boreholes varied in depth between 5.8 m (228 in.) to 9.5 m (372 in.).

Three measurements were made at each geotechnical borehole location: 1) a background reading with the detector positioned approximately 1 m above the ground, 2) a reading with the detector positioned on the surface of auger turnings removed from the holes (identified as auger spoils), and 3) readings of the gamma level as a function of depth in each borehole. A 5-cm x 5-cm (2-in. x 2-in.) NaI detector coupled with an EIC PRS-1 ratemeter/scaler was used.

3.2 SAMPLE COLLECTION AND ANALYSIS

During the fall of 1982, 120 surface and 34 trench sidewall soil samples were collected and sent to off-site EIC facilities for analysis. The samples, weighing approximately 700 g each, were analyzed wet and then dried and pulverized in a ball mill. The dried samples of approximately 400 g each were analyzed for uranium-238, radium-226, and thorium-232 in a 10-minute count. Nineteen of the 120 surface soil samples were also analyzed for thorium-230.

Fifty-nine surface soil samples (SS-1 to SS-59) were collected along the road from the southernmost gate. Samples were obtained at 6.1-m (20-ft) intervals on the center-line of the road and 3 m (10 ft) to either side. An additional 60 surface soil samples were collected from another 59 locations, ten of which were in areas of elevated gamma readings as identified by the gamma survey. The remainder of the samples were taken from the dikes and along the property boundary.

Thirty-four samples were collected from the sidewalls of 11 trenches. These samples were obtained from soil profiles of 30-cm (1-ft) increments to a depth of 90 cm (3 ft). The exception is Trench 11 in which buried trash was encountered.

Sludge samples from each of the four pits were analyzed for 29 elements, nitrates, fluorides, chlorides, sulfates, hydroxides, pH, and the following radionuclides: radium-226, radium-228, thorium-232, thorium-230, uranium-238, uranium-234, and uranium-235.

4.0 SURVEY RESULTS

This section presents the results of the direct measurements and soil sample analysis undertaken in this survey. All direct field measurements in this report represent gross readings. Background gamma levels averaged 6000 cpm.

4.1 DIRECT MEASUREMENTS

Results of direct gamma measurements are presented in Figure 4-1. The walkover scan identified several areas with elevated readings. Areas with the highest readings contained scrap material or were patchy areas void of vegetation. These areas are readily observable on site.

In November and December near-surface gamma- and surface beta-gamma characterization were conducted on a 1.5-m (5-ft) grid in areas where elevated readings were identified. Surveys conducted on the 1.5-m (5-ft) grid facilitated differentiation between background and elevated readings in areas where contamination was localized. Hatched areas in Figure 4-1 indicate areas where near-surface readings exceeded three times background.

Exposure rates were measured in 45 out of a possible 64 grid center locations. Two readings were in excess of 60 $\mu\text{R/h}$ (N98,250, W51,150 and N98,150, W50,950) which is the Nuclear Regulatory Commission (NRC) standard for continuous exposure to an individual in the general population (Ref. 2). The average reading for the site was 23 $\mu\text{R/h}$, which is below the standard. Exposure levels are indicated in Figure 4-2.

The results of gamma scintillation measurements performed in boreholes indicate that the contamination is confined to the upper 1 m (39 in.) of soil. Gamma readings taken in the shallow boreholes drilled in areas of elevated surface readings (SB-1 to SB-8) were reduced by up to factors of six in the first 30 cm

FIGURE 4-1 RESULTS OF DIRECT GAMMA MEASUREMENTS AT THE WSRP SITE

FIGURE 4-2 EXPOSURE RATES (μ R/h) AT THE WSRP SITE

(12 in.) of hole depth. Shallow borehole SB-2 had the highest surface gamma reading of 319,216 cpm and a reading at 30 cm (1 ft) of 73,262 cpm. Table 4-1 presents gamma measurements of the shallow boreholes. Gamma log background measurements and auger spoils readings from the geotechnical boreholes are presented in Table 4-2. Figure 4-3 shows the location of the gamma-logged boreholes.

4.2 SAMPLE ANALYSIS

Uranium-238 concentrations in surface soil samples ranged from 2 to 34,090 pCi/g. The highest concentration was found in SS-66 (N98,250, W51,150). The highest radium-226 concentration was 261.9 pCi/g from SS-65 (N98,245, W50,995). Resampling from this point reduced the concentration of radium-226 to 8.3 pCi/g. This is indicative of the inhomogeneity of the contamination in the area. The highest thorium-230 concentration, 370 pCi/g, and the highest thorium-232 concentration, 454.9 pCi/g, were from SS-60 (N98,045, W51,000). Soil samples from 15 locations exceeded the DOE draft guidelines presented in Table 4-3.

In all cases thorium-230 concentrations were either less than the guideline (see Table 4-3) or were associated with uranium and radium-226 concentrations that exceeded the applicable guidelines. This indicates that remedial actions based on uranium and radium-226 concentrations would ensure removal of thorium-230 concentrations that exceed 15 pCi/g. Therefore, monitoring for thorium-230 during remedial actions outside the raffinate pits would be required on a limited basis only.

Soil sample analysis and background levels of uranium-238, radium-226, thorium-230, and thorium-232 are presented in Tables 4-4 and 4-5. The locations where surface soil samples were collected are indicated in Figure 4-4. The locations of those samples exceeding guidelines are shown in Figure 4-5.

TABLE 4-1
GAMMA LOG OF SHALLOW BOREHOLES AT THE WSRP SITE
(Readings in cpm)

NUMBER		SB-1	SB-2	SB-3	SB-4	SB-5	SB-6 ^c	SB-7	SB-8	SB-9 ^d	SB-10 ^d	SB-11	SB-12 ^e
LOCATION ^a	N	98,045	98,115	98,115	98,210	98,235	98,245	98,245	98,250	98,800	99,000	99,605	99,915
	W	51,000	50,860	50,910	50,950	51,005	50,955	50,995	51,150	50,600	50,600	50,655	50,980
DEPTH (cm)	0	166,264	319,216	302,676	115,062	208,318	27,412	35,282	153,326	16,608	17,564	23,512	59,846
	15	130,984	219,938	176,318	74,964	191,080	21,790	22,270	101,290	16,162	14,050	23,898	52,804
	30	58,768	73,262	59,766	47,890	112,906	19,366	17,772	30,436	16,414	15,176	21,224	35,566
	45	26,308	46,446	24,926	26,880	82,414	17,304		19,020			17,294	26,074
	60	19,646	57,430	18,512	19,072	47,006	17,124	15,990	17,376	15,906	14,670	15,858	20,874
	75		42,356			29,012			16,312				18,768
	90	16,584	35,716 ^b	15,762	15,462	24,460	15,502	14,336	16,392	14,814	15,050	15,434	24,088
	105					19,282			17,380				25,972
	120	16,344		16,662	15,862	16,930	14,716	14,548	23,930 ^f			16,846	

^aSampling locations are shown on Figure 4-3.

^bCave in

^cPVC sleeve

^dHand drilled to 90 cm (36 in.)

^eOld hole with sediment

^fSediment

TABLE 4-2
GAMMA LOG OF GEOTECHNICAL BOREHOLES AT THE WSRP SITE
(Readings in cpm)

NUMBER	SB-1 ^b	SB-2 ^c	SB-3 ^c	SB-4 ^b	SB-5 ^c	SB-6 ^c	SB-7 ^c	SB-8 ^c	SB-9 ^c	SB-10 ^c	SB-11 ^c	SB-12 ^c	SB-13 ^c	SB-14 ^c	SB-15 ^c	SB-16 ^b	
LOCATION ^a N	98,470	98,740	98,760	98,825	99,000	99,220	99,230	99,250	99,275	99,420	99,595	99,600	99,880	99,940	100,010	100,050	
W	50,940	51,620	51,970	51,250	51,200	50,750	50,980	52,050	52,140	51,025	50,805	50,950	51,520	51,250	52,000	52,100	
DEPTH (in.) (cm)																	
0	0	4,962	9,554	7,790	7,350	9,326	9,868	14,746	9,178	4,736	9,464	10,376	6,476	30,284	14,218	14,460	10,502
12	30	12,718	14,564	13,718	14,048	14,344	12,414	18,070	11,684	2,260	11,704	12,770	11,892	26,450	14,974	12,308	14,216
24	61	15,366	15,512	15,718	15,254	15,606	12,774	16,292	12,404	2,856	13,084	14,302	13,526	16,640	14,458	12,392	15,616
36	91	15,152	15,780	15,430	14,372	15,798	13,434	15,166	12,322	7,524	13,768	14,558	13,480	15,412	15,040	12,454	16,406
48	122	14,474	16,214	14,470	14,180	15,056	14,098	15,584	12,738	10,954	14,000	14,354	13,168	14,980	15,310	13,574	16,364
60	152	13,466	15,524	13,818	13,410	14,852	13,678	15,380	13,278	12,554	14,642	13,900	14,072	15,802	15,716	13,938	15,988
72	183	12,248	14,724	13,360	13,044	14,462	13,858	15,194	12,662	11,006	14,230	14,298	13,950	15,856	15,728	14,096	15,294
84	213	12,278	14,034	13,474	12,822	14,358	13,202	14,722	13,132	10,076	14,756	14,552	14,164	14,760	14,466	14,464	14,650
96	244	11,466	13,660	13,050	11,894	13,870	12,220	14,384	12,908	11,662	14,232	14,676	13,516	15,232	14,568	14,480	13,410
108	274	10,378	13,838	11,830	10,264	13,034	13,246	13,706	12,434	12,042	14,344	14,220	13,488	15,396	13,956	14,174	12,458
120	305	10,502	13,572	11,370	10,412	13,442	13,380	14,460	12,804	11,738	14,540	13,336	13,584	15,236	12,016	14,810	12,304
132	335	10,410	13,630	11,306	10,982	13,834	13,218	14,492	13,688	10,586	15,084	13,318	13,592	15,734	11,530	15,666	11,822
144	366	9,976	12,610	11,610	10,748	13,494	13,014	15,246	13,426	9,408	14,726	13,110	13,660	15,070	12,170	15,942	11,530
156	396	9,936	12,238	12,132	10,790	13,250	12,836	15,408	13,684	9,518	14,678	12,784	13,070	16,136	12,122	15,216	11,992
168	427	9,638	12,130	12,050	10,734	12,532	13,054	15,146	14,684	9,918	12,980	12,744	12,254	16,708	11,624	15,506	12,260
180	457	10,000	12,100	12,038	9,908	12,274	12,948	13,104	14,674	10,340	14,792	12,336	11,268	16,134		15,778	12,328
192	488	10,466	13,088	12,986	10,808	11,948	12,382	11,846	13,456	10,216	14,496	11,760	10,972	16,364		15,590	12,132
204	518	10,442	13,206	13,834	11,860	12,610	12,012	11,324	13,046	9,806	14,256	11,142	9,838	15,256		16,314	12,062
216	549	10,674	13,100	13,528	11,058	12,588	11,522	11,098	13,666	9,702	14,456	8,710	11,504	15,256		15,712	11,272
228	579	10,738	12,552	12,698	10,530		11,666	11,178	14,660	10,342	13,832	8,354	9,270	14,516		15,874	7,030
240	610	11,360			10,390					8,936							7,314
252	640	11,338			9,282					7,466							7,202
264	671	10,860			6,408					6,070							6,662
276	701	10,956			5,224					5,856							6,694
288	732	10,640			4,418												5,468
300	762	10,552			5,980												6,186
312	792	10,102			6,370												5,630
324	823	9,920			3,682 ^d												6,418
336	853	9,818			3,630												6,670
348	884	10,520			2,886												6,108
360	914	10,492			1,892												8,958
372	945	9,972			1,584												6,038
384	975	11,236															5,476
396	1006																3,440

^aBorehole locations are shown on Figure 4-3.

^b6-in. diameter hole with 4-in. schedule 40 PVC.

^c8-in. diameter hole with 3-in. schedule 40 PVC.

^dProbe was in water.

FIGURE 4-3 LOCATION OF GAMMA-LOGGED BOREHOLES AT THE WSRP SITE

TABLE 4-3
RESIDUAL CONTAMINATION GUIDELINES FOR FORMERLY UTILIZED
SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES^a

Radionuclide	Concentration in Soil (pCi/g above background) ^{b,c,d}
Natural Uranium	75
A curie of natural uranium means the sum of 3.7×10^{10} dis/s from uranium-238 plus 3.7×10^{10} dis/s from uranium-234 plus 1.7×10^5 dis/s from uranium-235. One curie of natural uranium is equivalent to 3,000 kg or 6,600 lb of natural uranium.	
Uranium-238	150
Assumes that no other uranium isotopes are present.	
Radium-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm thick soil layer below the surface layer.
Radium-228	
Thorium-230	
Thorium-232	

^aAdapted from DOE (Ref. 3).

^bIn the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1. If both thorium-230 and radium-226 are presently, only the one present in the highest concentration should be included in the sum. If thorium-232 and/or radium-228 are present, it may be assumed that they are in secular equilibrium and only the term for thorium-232 should be included.

^cThese guidelines represent unrestricted-use residual concentrations above background averaged across any 15-cm thick layer to any depth and over any contiguous 100-m² surface area.

^dLocalized concentrations in excess of these limits are allowable provided that the average over 100 m² is not exceeded.

TABLE 4-4
RADIONUCLIDE CONCENTRATIONS IN
SURFACE SOIL SAMPLES FROM THE WSRP SITE
(pCi/g)

Page 1 of 3

Soil Sample	Location ^{a,b}	Uranium 238	Radium 226	Thorium 230	Thorium 232
SS-1	20 C	----	2.6+0.1	----	0.8+0.1
SS-2	20 R 10	----	0.9+0.1	----	0.2+0.1
SS-3	20 L 10	----	2.1+0.1	----	1.0+0.1
SS-4	40 C	----	1.0+0.1	----	0.3+0.1
SS-5	40 R 10	----	1.6+0.1	----	0.6+0.1
SS-6	40 L 10	----	3.7+0.1	----	1.5+0.1
SS-7	60 C	----	1.4+0.1	----	0.7+0.1
SS-8	60 R 10	----	1.8+0.1	----	1.4+0.1
SS-9	60 L 10	----	2.6+0.1	----	1.2+0.1
SS-10	80 C	----	2.5+0.1	----	1.5+0.2
SS-11	80 R 10	----	1.7+0.1	----	1.5+0.1
SS-12	80 L 10	----	1.1+0.1	----	1.3+0.1
SS-13	100 C	----	1.6+0.1	----	1.1+0.2
SS-14	100 R 10	----	1.6+0.1	----	1.3+0.2
SS-15	100 L 10	----	1.4+0.1	----	0.6+0.1
SS-16	120 C	----	3.2+0.1	----	1.4+0.1
SS-17	120 R 10	----	1.4+0.1	----	1.0+0.1
SS-18	120 L 10	----	3.2+0.1	----	1.3+0.1
SS-19	140 C	----	2.8+0.1	----	1.8+0.2
SS-20	140 R 10	----	2.5+0.1	----	2.0+0.2
SS-21	140 L 10	----	2.9+0.1	----	1.3+0.1
SS-22	160 C	----	2.0+0.1	----	1.6+0.1
SS-23	160 R 10	----	1.1+0.1	----	1.6+0.2
SS-24	160 L 10	----	1.9+0.1	----	0.7+0.1
SS-25	180 C	----	3.0+0.1	----	1.5+0.1
SS-26	180 R 10	----	1.6+0.1	----	1.4+0.1
SS-27	200 C	----	3.7+0.1	----	PNP
SS-28	200 R 10	----	1.2+0.1	----	1.2+0.1
SS-29	200 L 10	----	1.2+0.1	----	0.4+0.1
SS-30	220 C	----	2.3+0.1	----	1.1+0.1
SS-31	220 R 10	----	1.2+0.1	----	1.3+0.1
SS-32	220 L 10	----	1.8+0.1	----	0.6+0.2
SS-33	240 C	----	1.4+0.1	----	1.3+0.1
SS-34	240 R 10	----	1.9+0.1	----	1.5+0.1
SS-35	240 L 10	----	0.7+0.1	----	PNP
SS-36 ^c	260 C	----	1.3+0.1	----	1.2+0.1
SS-37 ^c	260 R 10	----	0.9+0.1	----	1.2+0.2
SS-38 ^c	260 L 10	----	1.0+0.1	----	0.4+0.1
SS-39	280 C	----	1.8+0.1	----	1.6+0.2
SS-40	280 R 10	----	1.6+0.1	----	1.7+0.2
SS-41	280 L 10	----	1.4+0.1	----	0.8+0.1
SS-42	300 C	----	2.2+0.1	----	0.7+0.1

TABLE 4-4
(continued)

Page 2 of 3

Soil Sample	Location	Uranium 238	Radium 226	Thorium 230	Thorium 232
SS-43	300 R 10	----	1.5+0.1	----	1.3+0.1
SS-44	300 L 10	----	1.3+0.1	----	0.3+0.1
SS-45	320 C	----	0.9+0.1	----	1.7+0.2
SS-46	320 R 10	----	1.2+0.1	----	1.4+0.1
SS-47	320 L 10	----	1.4+0.1	----	0.8+0.1
SS-48	340 C	----	1.4+0.1	----	1.5+0.2
SS-49	340 R 10	----	1.2+0.1	----	1.3+0.1
SS-50	340 L 10	----	1.5+0.1	----	1.4+0.2
SS-51	360 C	----	1.5+0.1	----	1.2+0.2
SS-52	360 R 10	----	1.3+0.1	----	1.7+0.2
SS-53	360 L 10	----	1.8+0.1	----	1.3+0.2
SS-54	380 C	----	0.9+0.1	----	1.5+0.1
SS-55	380 R 10	----	1.2+0.1	----	0.7+0.1
SS-56	380 L 10	----	1.3+0.1	----	1.4+0.2
SS-57	400 C	----	1.1+0.1	----	0.4+0.1
SS-58	400 R 10	----	2.0+0.1	----	1.6+0.1
SS-59	400 L 10	----	1.5+0.1	----	1.6+0.1
SS-60	N98,045 W51,000	919.8+22.4	213.8+3.3	370+40	454.9+4.2
SS-61	N98,115 W50,860	23530+79.9	2.7+1.4	----	12.0+1.4
SS-62	N98,115 W50,910	6337+49.7	15.1+1.5	----	6.5+1.1
SS-63	N98,210 W50,950	7375+44.4	17.7+1.4	70+7.0	2.4+0.9
SS-64	N98,235 W51,005	11730+59.2	6.8+1.2	----	0.4+0.5 ^d
SS-65	N98,245 W50,995	4893+39.2	261.9+3.9	----	2.2+1.6
SS-65 ^e	N98,245 W50,995	676+17.6	8.3+0.7	----	6.7+0.7
SS-66	N98,250 W51,150	34090+97.3	1.9+2.1	4.2+0.6	PNP
SS-67	N98,300 W50,900	6.6+0.7	1.6+0.1	----	----
SS-68	N98,500 W51,000	16.0+1.2	3.7+0.2	----	----
SS-69	N98,500 W51,100	117.2+8.1	2.5+0.5	----	1.1+0.6
SS-70	N98,500 W51,300	218.4+13.1	3.1+0.6	4.3+0.2	1.3+0.5
SS-71	N98,600 W51,000	8.3+4.3	2.6+0.4	----	2.7+0.4
SS-72	N98,600 W51,200	6.1+1.1	1.4+0.3	----	1.5+0.4
SS-73	N98,600 W51,400	2.7+1.8	1.6+0.4	----	2.0+0.4
SS-74	N98,600 W51,600	7.4+3.2	2.0+0.6	----	1.3+0.4
SS-75	N98,600 W51,700	48.5+8.3	2.2+0.4	2.3+0.2	2.2+0.3
SS-76	N98,700 W50,700	11.0+0.6	1.2+0.1	----	----
SS-77	N98,700 W51,000	79.8+6.9	1.5+0.4	3.6+0.3	2.1+0.4
SS-78	N98,700 W51,200	2.8+2.3	2.2+0.3	----	1.8+0.3
SS-79	N98,700 W51,300	2.5+2.0	2.0+0.3	----	1.2+0.2
SS-80	N98,700 W51,500	9.5+3.5	2.0+0.4	----	2.1+0.3
SS-81	N98,700 W51,600	3.4+2.9	2.0+0.3	----	2.4+0.4
SS-82	N98,700 W51,800	9.5+2.8	1.9+3.0	----	1.9+0.4
SS-83	N98,800 W50,600	19.5+0.3	3.4+0.1	----	----
SS-84	N98,900 W50,900	2.0+0.2	1.2+0.1	----	----
SS-85	N99,000 W50,600	20.4+0.3	2.3+0.0	----	----
SS-86	N99,000 W51,000	10.1+0.4	1.3+0.1	----	----

TABLE 4-4

(continued)

Page 3 of 3

Soil Sample	Location		Uranium 238	Radium 226	Thorium 230	Thorium 232
SS-87	N99,000	W51,100	51.2+5.1	19.0+1.2	----	1.1+0.5
SS-88	N99,100	W50,900	6.1+1.0	2.0+0.1	----	----
SS-89	N99,100	W51,300	12.2+3.9	2.3+0.4	----	2.0+0.6
SS-90	N99,100	W51,500	36.2+4.4	0.2+0.4	----	1.2+0.7
SS-91	N99,200	W50,600	13.2+0.2	1.5+0.0	----	----
SS-92	N99,200	W50,800	12.5+1.2	3.9+0.2	----	----
SS-93	N99,200	W51,000	8.3+0.8	1.2+0.1	----	----
SS-94	N99,300	W50,700	21.2+1.2	1.8+0.1	----	----
SS-95	N99,300	W50,900	7.2+0.6	1.7+0.1	----	----
SS-96	N99,300	W51,500	9.9+4.2	3.0+0.4	----	1.9+0.4
SS-97	N99,400	W50,600	28.2+1.2	1.4+0.1	----	----
SS-98	N99,400	W50,800	16.1+0.9	1.0+0.1	----	----
SS-99	N99,400	W51,000	10.7+3.4	2.6+0.6	----	1.8+0.5
SS-100	N99,500	W50,700	15.4+1.0	1.1+0.1	----	----
SS-101	N99,500	W50,900	5.0+0.1	1.1+0.1	----	----
SS-102	N99,500	W51,500	3.2+4.3	1.2+0.4	----	1.6+0.5
SS-103	N99,500	W52,200	7.9+5.3	2.3+0.5	----	3.6+0.6
SS-104	N99,600	W50,600	66.0+1.1	1.6+0.1	----	----
SS-105	N99,600	W50,800	20.6+1.0	1.6+0.1	----	----
SS-106	N99,600	W51,000	14.3+2.3	1.3+0.3	----	1.5+0.3
SS-107	N99,800	W51,000	12.9+1.9	17.8+0.9	11.0+1.0	1.1+0.4
SS-108	N99,800	W52,200	6.8+2.3	2.3+0.3	2.1+0.1	2.9+0.3
SS-109	N99,900	W51,100	2.5+3.3	8.0+0.7	9.8+0.4	2.5+0.5
SS-110	N99,900	W51,300	4.5+2.6	2.5+0.3	3.8+0.2	1.7+0.3
SS-111	N99,900	W51,500	12.2+1.8	2.4+0.3	7.1+0.3	1.4+0.5
SS-112	N99,900	W52,200	8.5+3.6	2.6+0.4	3.1+0.2	1.8+0.4
SS-113	N100,000	W51,400	161.9+9.6	2.2+0.5	7.8+0.5	2.7+0.5
SS-114	N100,000	W51,600	24.5+3.5	2.0+0.6	3.8	0.0+0.4
SS-115	N100,000	W51,800	3.6+5.1	2.0+0.4	3.6	
SS-116	N100,000	W52,000	5.4+2.7	2.1+0.4	1.0+0.1	
SS-117	N100,000	W52,100	33.5+4.5	2.0+0.3	2.1+0.1	
SS-118	N100,100	W52,000	21.4+4.2	6.0+0.6	5.1+0.4	+0.5

^aSampling locations are shown in Figure 4-4.

^bUnless otherwise noted, all samples were dried, ball-milled, and counted. SS-1 through SS-59 were taken along the road starting from the southernmost end of the site. The intersection of the fence and road is point 0. Measurements were taken in 6.1-m (20-ft) intervals on the road centerline (C), 3 m (10 ft) to the right (R 10) and 3 m (10 ft) to the left (L 10). SS-60 through SS-118 were taken on the AEC grid.

^cSample taken from 5-cm (2-in.) depth

^dInitial count of wet sample

^eResample

PNP Peak not present (not detectable)

TABLE 4-5

BACKGROUND RADIATION LEVELS AND NUCLIDE CONCENTRATIONS IN SURFACE SCIL SAMPLES IN THE STATE OF MISSOURI

Sample Designation	Description of Sample Location	Average External Gamma Exposure Rate (uR/h) ^a	Nuclide Concentration in Surface Soil (pCi/g) ^b		
			Radium-226	Thorium-232	Uranium-238
MO-1	Approx. 45 km E of Kansas City, Missouri, in pasture field on S side of I-70	6.0	1.4 $\pm$ 0.04	1.3 $\pm$ 0.10	1.7
MO-2	Approx. 140 km E of Kansas City, Missouri, at intersection of I-70 and exit J, SE corner	10.0	1.3 $\pm$ 0.06	1.2 $\pm$ 0.10	1.3
MO-3	Rest stop on S side of I-70, ~16 km E of Williamsburg, Missouri	6.7	1.1 $\pm$ 0.06	1.0 $\pm$ 0.08	1.2
MO-4	SE corner of intersection of Hwy 175 and I-70 in O'Fallon, Missouri	7.5	1.3 $\pm$ 0.08	1.1 $\pm$ 0.12	1.1
MO-5	Approx. 34 km N of Missouri-Arkansas border, on E side of I-55, mile marker 21	8.1	1.2 $\pm$ 0.04	1.2 $\pm$ 0.06	1.3
MO-6	E side of I-55, ~14 km N of intersection with Hwy Alt. 61, at mile marker 76	5.4	0.31 $\pm$ 0.04	0.32 $\pm$ 0.04	0.33
MO-7	E side of I-55, ~1.6 km S of Appleton exit E of Friedheim, Missouri	7.6	1.1 $\pm$ 0.06	1.1 $\pm$ 0.06	1.1
MO-8	Exit 0 off I-55, near Bloomsdale, Missouri	6.8	0.83 $\pm$ 0.04	0.76 $\pm$ 0.06	0.81
MO-9	E side of I-55, ~0.4 km S of Hwy 141 intersection, Maxville, Missouri	5.1	1.1 $\pm$ 0.06	1.1 $\pm$ 0.06	1.1
MO-10	W side of Hwy 367, ~0.3 km S of intersection with Hwy 67, N of St. Louis, Missouri	4.6	1.0 $\pm$ 0.10	0.95 $\pm$ 0.14	0.76

^aExposure rate determined from 3 to 4 measurements at each location using a "Phil" tube.

^bStandard deviation of radium-226 and thorium-232 measurements are given as the 2 σ value. Error in the uranium-238 measurements are $\leq$ 5% (2 σ).

Source: Oak Ridge National Laboratory (Ref. 4).

FIGURE 4-4 LOCATION OF SURFACE SOIL SAMPLES AT THE WSRP SITE

FIGURE 4-5 LOCATION OF SURFACE SOIL SAMPLES EXCEEDING URANIUM-238, RADIUM-226, AND THORIUM-232 GUIDELINES AT THE WSRP SITE

None of the samples obtained from the side walls of the trenches exceeded guidelines for uranium-238, radium-226, and thorium-232. Table 4-6 presents sample analysis from the trench samples and Figure 4-6 indicates the locations of those samples.

Analysis of the sludge samples from the raffinate pits is presented in Table 4-7. Thorium-230 is the greatest contributor to the radioactivity of the samples. The isotopic distribution is in agreement with that expected in residues from the processing of uranium and thorium concentrates.

TABLE 4-6
RADIONUCLIDE CONCENTRATIONS IN SIDEWALL
TRENCH SAMPLES FROM THE WSRP SITE
(pCi/g)

Page 1 of 2

Number	Location ^a	Depth (ft)	Uranium 238	Radium 226	Thorium 232 ^b
TR-1	N98,350, W50,910	0-1	1.5 ± 0.3	0.9 ± 0.2	1.4 ± 0.4
		1-2	1.0 ± 0.5	1.1 ± 0.1	1.2 ± 0.3
		2-3	1.7 ± 3.8 ^b	1.4 ± 0.2	0.9 ± 0.4
TR-2	N98,420, W51,230	0-1	20.0 ± 1.1	1.1 ± 0.1	1.3 ± 0.5
		1-2	4.4 ± 0.0	1.0 ± 0.0	0.8 ± 0.2
		2-3	<1.0 ^b	1.0 ± 0.1	<0.5
TR-3	N98,570, W51,520	0-1	2.7 ± 0.4	1.1 ± 0.1	0.9 ± 0.2
		1-2	<1.0 ^b	0.8 ± 0.2	0.6 ± 0.4
		2-3	<1.0 ^b	1.3 ± 0.2	0.8 ± 0.3
TR-4	N98,700, W52,030	0-1	1.6 ± 0.3	1.0 ± 0.1	1.1 ± 0.2
		1-2	0.4 ± 0.8	1.3 ± 0.2	0.7 ± 0.3
		2-3	1.1 ± 0.7	0.9 ± 0.2	0.9 ± 0.4
TR-5	N98,840, W52,075	0-1	0.3 ± 0.5	1.0 ± 0.2	0.9 ± 0.4
		1-2	0.7 ± 0.5	1.2 ± 0.1	1.2 ± 0.4
		2-3	1.6 ± 0.5	1.1 ± 0.1	0.9 ± 0.2
TR-6	N98,955, W51,080	0-1	1.3 ± 1.6 ^b	1.0 ± 0.1	1.2 ± 0.4
		1-2	0.6 ± 1.0	1.2 ± 0.1	<0.5
		2-3	1.5 ± 0.4	1.0 ± 0.1	0.8 ± 0.4
TR-7	N99,455, W52,260	0-1	<1.0 ^b	0.8 ± 0.1	0.3 ± 0.1
		1-2	0.7 ± 0.7	0.9 ± 0.2	0.1 ± 0.9
		2-3	0.6 ± 0.4	1.6 ± 0.1	1.1 ± 0.3
TR-8	N99,625, W52,390	0-1	<1.0 ^b	1.2 ± 0.2	0.8 ± 0.3
		1-2	<1.0 ^b	1.0 ± 0.2	1.0 ± 0.3
		2-3	0.9 ± 0.5	1.2 ± 0.1	1.1 ± 0.3
TR-9	N99,950, W51,070	0-1	3.9 ± 0.6	1.1 ± 0.2	0.8 ± 0.2
		1-2	1.3 ± 0.6	1.0 ± 0.1	<0.5
		2-3	<1.0 ^b	1.6 ± 0.2	1.3 ± 0.4
TR-10	N99,990, W51,530	0-1	4.5 ± 0.5	1.0 ± 0.1	1.1 ± 0.3
		1-2	<1.0 ^b	0.8 ± 0.4	0.1 ± 0.3
		2-3	0.6 ± 0.4	1.0 ± 0.1	0.5 ± 0.3

TABLE 4-6
(continued)

Page 2 of 2

Number	Location	Depth (ft)	Uranium 238	Radium 226	Thorium 232 ^b
TR-11	N99,990, 51,540	Sewer Pipe 12-14"	6.3 ± 0.8	1.2 ± 0.1	<0.5
TR-12	N100,080, W52,040	0-1	1.8 ± 0.4	1.0 ± 0.1	0.8 ± 0.2
		1-2	2.4 ± 1.5^b	1.2 ± 0.1	1.4 ± 0.3
		2-3	$<1.0^b$	1.3 ± 0.2	0.8 ± 0.4

^aSampling locations are shown on Figure 4-6.

^bPreliminary analysis

TABLE 4-7
RADIONUCLIDE CONTENTS OF THE
WELDON SPRING RAFFINATE PITS
(pCi/g dry)

Radionuclide	Pit 1	Pit 2	Pit 3	Pit 4
Radium-226	430 $\pm$ 130	440 $\pm$ 130	460 $\pm$ 130	11 $\pm$ 3
Radium-228	850 $\pm$ 85	200 $\pm$ 20	100 $\pm$ 10	60 $\pm$ 10
Thorium-232	100 $\pm$ 20	120 $\pm$ 20	120 $\pm$ 20	120 $\pm$ 20
Thorium-230	24000 $\pm$ 1000	24000 $\pm$ 1000	14000 $\pm$ 1000	1600 $\pm$ 100
Uranium-238	710 $\pm$ 70	470 $\pm$ 40	520 $\pm$ 50	620 $\pm$ 60
Uranium-234	810 $\pm$ 80	560 $\pm$ 50	570 $\pm$ 50	610 $\pm$ 60
Uranium-235	40 $\pm$ 5	30 $\pm$ 4	30 $\pm$ 4	30 $\pm$ 4

5.0 SUMMARY AND SIGNIFICANCE OF FINDINGS

A comprehensive radiological survey of the WSRP site was conducted in 1982 and 1983 by BNI/EIC. The survey included surface radiation scans, measurements of direct radiation levels, and analyses for radionuclide concentrations in soil samples, both surface and subsurface.

The results of the survey indicate areas of elevated direct radiation levels and surface soil contamination exceeding guidelines. Areas of elevated uranium-238 concentrations are primarily in the southern area of the site. These locations are visually identifiable. They consist of bare patches (alkaline in appearance) or scrap material. The contamination appears to be confined to the surface or near-surface layers, as confirmed by subsurface sampling, gamma logs of boreholes, and resampling from contaminated areas. Elevated radium-226 concentrations were found at several locations on the downhill (northeast) slope of Raffinate Pit 3. This area is in the path of the old slurry lines from the WSCP.

Although there are areas of contamination exceeding guidelines, most of the site is below guidelines for uranium-238, radium-226, thorium-230, and thorium-232. Sludge samples from the Raffinate Pits indicate a mixture of radionuclides differing from natural equilibrium. Uranium concentrates typically may contain up to five percent thorium (Ref. 5). Processing of these concentrates would then produce a thorium-enriched residue accounting for the elevated concentrations of thorium-230 in the sludge.

The average exposure rate on site was 23 $\mu\text{R/h}$. This is below the 60 $\mu\text{R/h}$ standard for unrestricted exposure of the general public. This site is a restricted area, which further limits the exposure of individuals.

REFERENCES

1. NLO, Inc. Environmental Monitoring Program for the DOE Weldon Spring Missouri Site, NCLO-009EV (SPECIAL), Cincinnati, OH, 1981.
2. U. S. Code of Federal Regulations. 10 CFR 20.105, "Permissible Levels of Radiation in Unrestricted Areas," Washington, D.C., January 1983.
3. U.S. Department of Energy. "Interim Planning Guidelines and Criteria for Residual Radioactive Materials at Formerly Utilized Sites Remedial Action Program (FUSRAP) and Remote Surplus Facilities Management Program (SFMP) Sites" (Draft), July 11, 1984.
4. Oak Ridge National Laboratory. State Background Radiation Levels: Results of Measurements Taken During 1975-1979, ORNL/TM-7343, Oak Ridge, TN, 1981.
5. U.S. Nuclear Regulatory Commission. Office of Nuclear Material Safety and Safeguards. Generic Environmental Impact Statement on Uranium Milling, (draft), NUREG-0511, Volume 2, Washington, DC, April 1979.