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March 1979

Prepared for
Rockwell Hanford Operations
A Prime Contractor for the
U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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PNL-1948

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Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy $____*; Microfiche $3.00

*Pages	NTIS Selling Price
001-025	$4.00
026-050	$4.50
051-075	$5.25
076-100	$6.00
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This report was sponsored by
Rockwell Hanford Operations
A Prime Contractor for the
U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Richland, Washington 99352

ACKNOWLEDGMENTS

This report is published with funds from the Department of Energy (formerly the Energy Research and Development Administration) under support contract to the Rockwell Hanford Operations (formerly Atlantic Richfield Hanford Company, ARHCO).

We thank Keith Price and Harold Maxfield of ARHCO for suggesting and helping to scope the project and for reviewing the manuscript. The field work could not have been done without the excellent cooperation of N. K. Pope of ARHCO who provided radiation monitoring services throughout the study. Larry Hutton of ARHCO did the field survey and provided the readings in Appendix II. Art Case of Battelle did the gamma energy analyses; ^{90}Sr analyses were done by U.S. Testing. Backhoe excavations were done by Curtis Hagen of ARHCO. Several of the research aspects of this study were supported either directly or indirectly through on-going projects funded by V. A. Uresk for ARHCO.

Field observations and collections of biological materials were done with the help of M. J. Harris, M. A. Combs, L. E. Rendall, D. T. McCullugh, and K. A. Gano. Annual growth ring analyses in Appendix I were provided by M. J. Harris. Scotty Getchell took the photographs.

EXECUTIVE SUMMARY

The 216-A-24 Crib was built in 1957 and was used from 1958 to 1966 to receive condensate from the 241-A and 241-AX Tank Farms. As of December 1974, the crib still retained an estimated 385 Ci of ^{137}Cs and 27 Ci of ^{90}Sr. In 1975, rabbitbrush plants (Chrysothamnus nauseosus) growing on the crib were found to contain radioactive materials.

Highest levels of activity and densest stands of rabbitbrush plants were in the center of the second section of the crib where a Geiger-Müller count rate meter showed surface exposure rates of certain plants to be as high as 125 times background. Of the 519 shrubs on the second section, 364 were at background, 62 were up to 10 times background, and 93 were over 10 times background. Contaminated shrubs were restricted to the center of the crib. All shrubs more than 6 meters away from the centerline were at background levels. The shrubs were, on the average, 9.4 years old (range 6-12 years).

The radionuclide involved was primarily ^{137}Cs. Other fission products were observed, but levels were at or near detection limits. Soil excavations showed that rabbitbrush plants were sufficiently deep-rooted to reach the gravel drainfield which is at the 8 foot depth in the shallow end of this crib section. The shrubs appeared to absorb ^{137}Cs and trace amounts of other fission products from within or below the gravel layers. The gravel appeared to retain significant amounts of ^{137}Cs. Soil above the gravel layers was not contaminated although there were detectable levels of ^{137}Cs in the rabbitbrush roots which grew through that soil. Cesium-137 was detectable in the upper cm of soil and in the litter, especially beneath canopies of plants with high levels of ^{137}Cs in their leaves. However, at the 15 cm depth, ^{137}Cs was not detectable in the soil. Consequently, deep excavation will not be required for decontamination.

Some animal samples collected on the crib contained ^{137}Cs. Those insect species associated with a rabbitbrush shrub containing ^{137}Cs and its litter showed higher levels of ^{137}Cs than other wider-ranging species caught in pitfall traps and by hand. Two out of seven pocket mice contained detectable amounts of ^{137}Cs with 70% of the total body burden in the muscle and skeleton.

Recommendations for restoration of the crib surface, if appropriate, include eradication of rabbitbrush plants, removal of the surface centimeter of soil on the central 12 meters of the crib, removal of the cobble layer from the surface, installation of a one-foot layer of clean soil and revegetation of the surface with cheatgrass. An effort should be made to keep road traffic off the new surface so that plants can maintain continuous cover.

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RADIOACTIVITY ASSOCIATED WITH BIOTA AND SOILS OF THE 216-A-24 CRIB

1. INTRODUCTION

The 216-A-24 Crib is located east of the 200 East area outside the exclusion fence. It is approximately 0.9 miles from the main road connecting the Wye Barricade and the 200 East area main gate. The approximate coordinates are N 42206, W 46854 to N 42494, W 45328.

The crib was constructed in late 1957. Between May, 1958, and January, 1966, it received condensates from the boiling waste storage tanks in the 241-A and 241-AX Tank Farms (Lundgren, 1970). Table 1.1 shows the radioactivity delivered to the crib and that remaining after decay as of December 1, 1974. Cesium-137 is the predominant radionuclide being 14 times as concentrated as ^{90}Sr on a curie basis. Other nuclides, such as ^{106}Ru and ^{60}Co, are present in small amounts. These radionuclides are presumably distributed throughout the length of the crib.

TABLE 1.1. Radioactivity Remaining in the 216-A-24 Crib as of December 31, 1974. Data are from Anderson, 1975.

	Remaining Dec. 31, 1974 (curies)
Beta	795
^{90}Sr	27.0
^{106}Ru	0.069
^{137}Cs	385
^{60}Co	0.093

The structure of the crib is shown in Figure 1.1. It consists of four sections, each 350 feet long. Condensates from the tank farm were delivered to the head of the crib and drained into a gravel drainfield through perforations in a 15-inch-diameter pipe. Depth of this perforated pipe from finished grade varies from about 15 feet at the upper end of each crib section to about 8 feet at the lower end of each section. The pipe is covered with gravel over which a polyethylene sheet was installed to prevent sand from the overlying backfill material from sifting into the gravel bed. This sheet, while still intact, would also discourage penetration of plant roots into the drainfield.

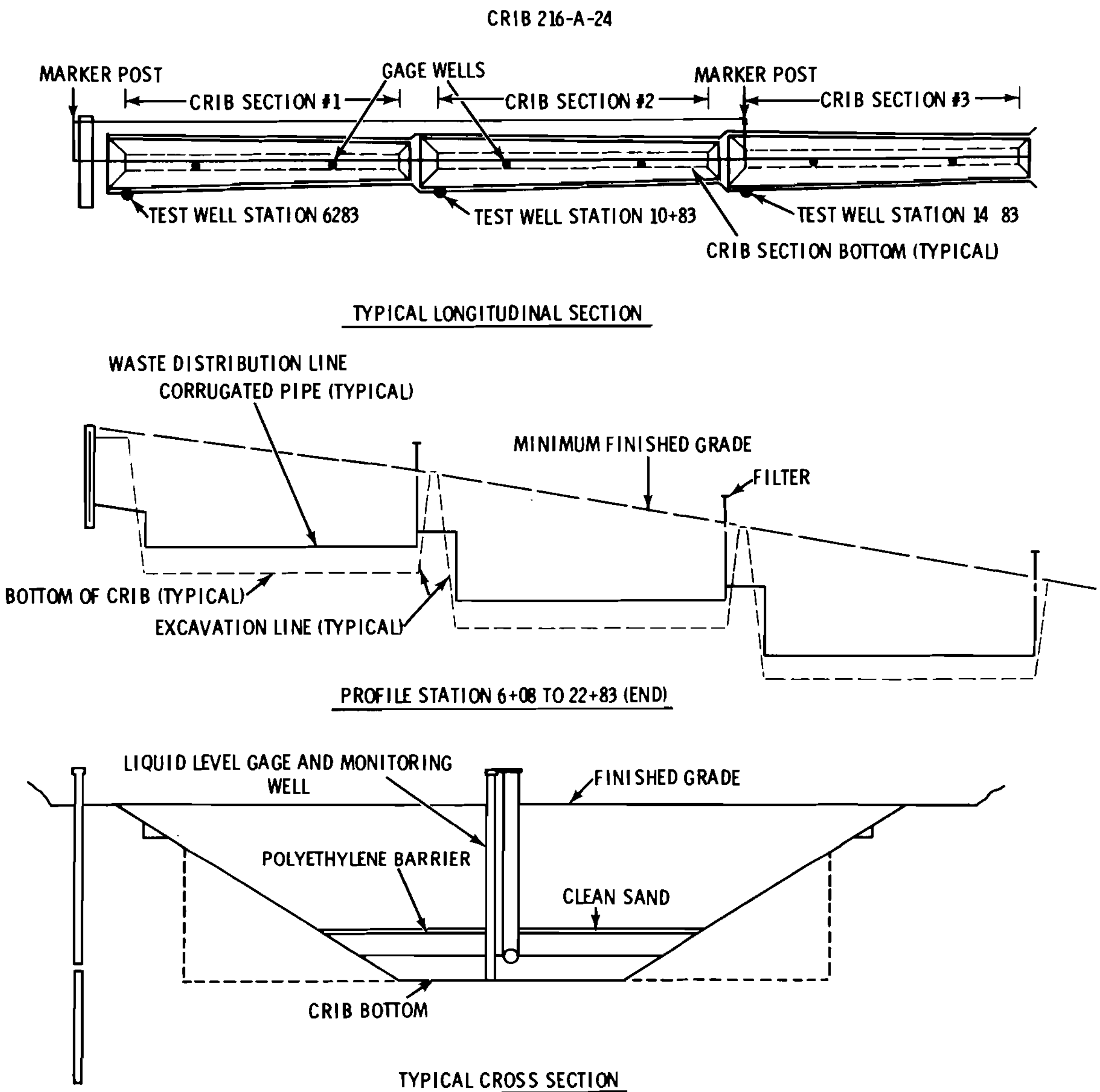


FIGURE 1.1. Structural Details of the 216-A-24 Crib

In the spring of 1975, plants growing on this crib were found to emit sufficient radioactivity to register significantly above background in routine radiation monitoring. Presumably, roots of these plants were absorbing radioactive materials from deep in the soil profile or directly from the gravel bed. However, shrubs adjacent to one another were found to contain levels of radioactivity different by orders of magnitude, indicating that rooting depth or extent, species specific uptake characteristics, or bush size or vigor might be implicated.

Work reported in this document was done to investigate the surface soils, plants, and animals on the crib with the following objectives in mind.

- Document location, approximate age, and level of radioactivity in shrubs on the part of the 216-A-24 Crib shown as Section II in Figure 1.1 and determine the major nuclides involved.
- Determine from the observed distribution pattern of contaminated plants the probable source of contamination and the reason for the apparently erratic spatial distribution of contaminated shrubs on the crib, including root system excavation studies if permissible.
- Document any spread of radioactivity from contaminated foliage of the bushes to other plant and animal species on the crib.
- Suggest methods which might be used to restore the surface to stable, non-radioactive condition and to prevent future occurrences of similar problems.

2. SOILS AND PLANT AND ANIMAL SPECIES ON THE CRIB

The 216-A-24 Crib is covered with backfill material which consists mostly of the sandy soils native to the area. However, cobble layers occur about 2-3 meters below the surface in the native profile and some rocks from these cobble layers are mixed with soil in the backfill material. When the crib was constructed, large cobbles were spread to stabilize the surface against wind erosion (K. R. Price, personal communication).

Plant cover is dominated by two species: rabbitbrush (Chrysothamnus nauseosus), a perennial shrub, and cheatgrass (Bromus tectorum), an annual grass. There are scattered sagebrush (Artemisia tridentata) among the rabbitbrush. Occasional herbs other than cheatgrass were found in a survey in early May. These included substantial amounts of Holosteum umbellatum, Descurainia pinnata, and Festuca octoflora; moderate amounts of Cryptantha circumscissa, Sisymbrium altissimum, Salsola kali, and Ambrosia acanthicarpa; and small amounts of Lomatium macrocarpus, Microsteris gracilis, Poa secunda, and a species of Oenothera.

Cheatgrass stands are sparse in areas where cobbles cover the soil surface and are more luxuriant beneath shrubs and in areas where the surface material is soil. Cheatgrass shoots beneath shrub canopies are lighter green, larger and more succulent than those between bushes. This could be important if the more succulent plants are more palatable to animals because cheatgrass growing beneath contaminated shrubs was found to contain radiocesium. (See Section 5, Table 5.2.)

The second section of the crib was chosen as an intensive study area (Figure 2.1, Photograph 1). The upper (western) end of the section is sparsely populated with bushes, but a dense stand occurs in the lower end; and, as will be discussed in the next chapter, most of the shrubs containing radionuclides occur in the lower half of the section. Therefore, the crib section was divided into three parts: an upper section extending 53 m from the large, green vent; a middle section 44 m in length, the center of which was mapped in detail (Photographs 2 and 3); and a lower section 26 m long extending from the lower monitoring well to the lower green vent. The crib radiation zone is 37 m wide. Bush densities (numbers per 500 m^2) on these three sections are given in Table 2.1. Compared to two other areas nearby, the 216-A-24 Crib has more rabbitbrush and less sagebrush, but a total density of bushes per unit area comparable to an area near the REDOX plant.

A transect was laid down the center of the crib in the area marked in Figure 2.1 as "mapped area" (Photograph 4). All shrubs overlapping this transect were sampled to determine approximate age from growth rings in transverse stem sections. Stems were cut near the ground surface for

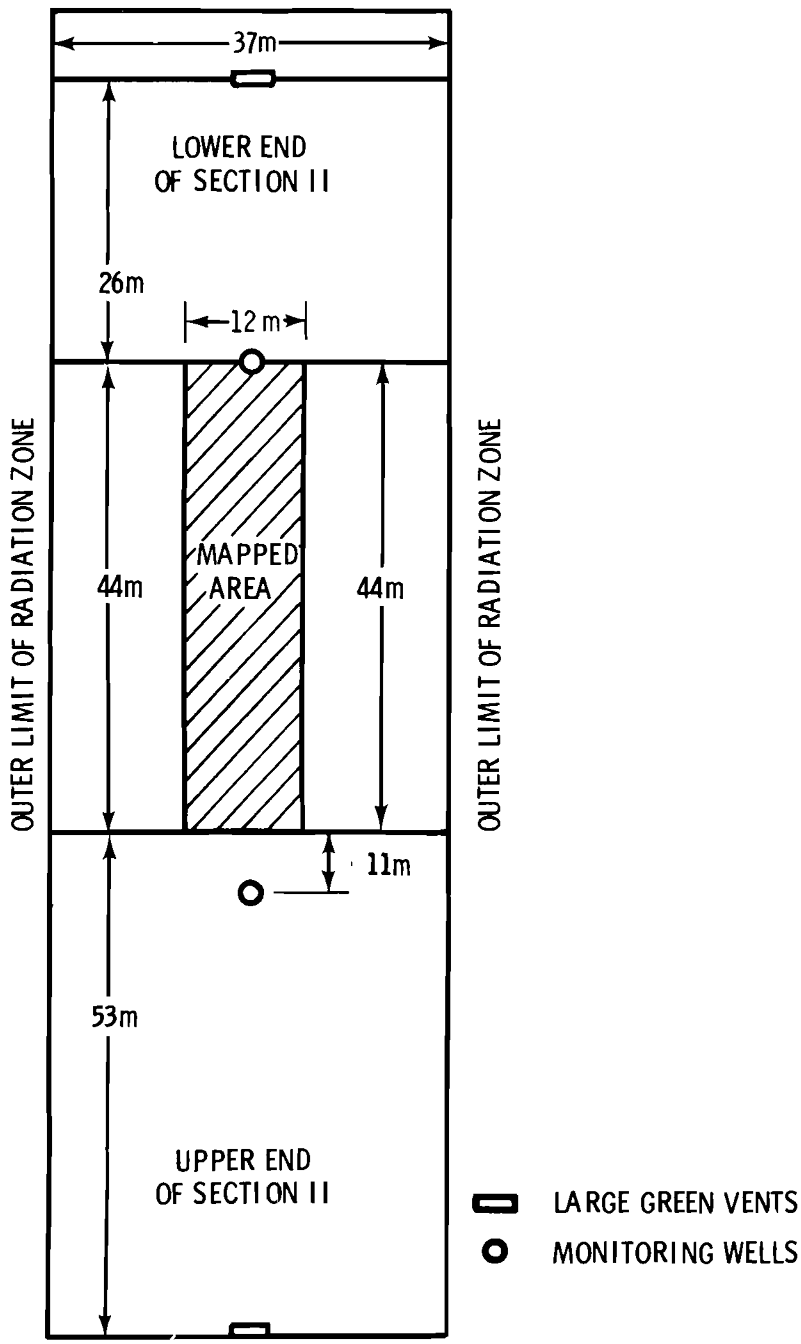


FIGURE 2.1. Diagram Showing Section II of the Crib and the Location of the Mapped Area

TABLE 2.1. Comparison of Shrub Density (number per 500 m^2) on the Second Section of the 216-A-24 Crib with Values for the B-C Crib Control Area and the REDOX Area (Comparison Data from Cline, Uresk, and Rickard, 1975)

	Density (number per 500 m^2)					
	216-A-24					
Plant	Upper	Middle	Lower	Total	B-C	REDOX
Sagebrush	2	0.3	2.1	1	186	42
Rabbitbrush	16.6	95	68	56	2	13
Total	18.6	95.3	70.1	57	188	55

examination. An assumption was made that the first ring visible in the center of the stem section was from the end of the third year since germination. A further assumption was made that one growth ring indicates one year's growth. This assumption was probably valid since rabbitbrush loses its leaves each year, thus giving a definitive end to the growth period. Furthermore, the climatic pattern (wet winter, dry summer) should accentuate the annual growth ring pattern. Data given in Appendix I show that plants in the center of the crib are 6 to 12 years old with an average age of 9.4 years. They range in height from 40 cm to 88 cm and average 64 cm.

Vertebrate animals which would be expected to live on or near the crib or to pass over the crib include snakes, lizards such as the side-blotched lizard (Uta stansburiana), numerous bird species, occasional mule deer (Odocoileus hemionus), black-tailed hares (Lepus californicus), and a number of small mammals, especially the Great Basin pocket mouse (Perognathus parvus), deer mouse (Peromyscus maniculatus), and grasshopper mouse (Onychomys leucogaster).

On May 1 and 2, twenty-five small mammal traps were set on the second section of the A-24 Crib. On May 1, these yielded four Great Basin pocket mice (2 males, 2 females) and on May 2, three of the same species (1 male, 2 females). Four large mammal traps set on these two nights were unsuccessful. These trapping results indicate that populations of mammals on the crib were relatively sparse.

Invertebrates on the crib surface in early May included a number of species of beetles, leafhoppers, bugs, flies, thrips, lepidopterans, mites, hymenopterans, and ants. The most noticeable populations to the casual observer were harvester ants, which had a total of 104 nests on the crib surface (Table 2.2, Photograph 7), and those insects associated with shrub

TABLE 2.2. Harvester Ant (Pogonomyrmex owyheei) Colony Density (numbers per crib section) within Crib 216-A-24

Section	Live	Dead	Total
1	20	3	23
2	25	6	31
3	22	4	26
4	23	1	24
Total	90	14	104

canopies (Table 2.3). Twenty pitfall traps, placed on Section II of the crib on May 1 and left in place for 15 days, yielded 15 Tenebrionidae (Eleodes hispilabris) and 10 Curculionidae (Ophryastes sp.), both common ground-dwelling beetles on the 200 Area plateau.

Quantitative information on a single nest of the harvester ant (Pogonomyrmex owyheei) was obtained on May 13 for a nest adjacent to the crib. The numbers of ants, chambers in the nest, and estimates of the volume of soil excavated at several depths are given in Table 2.4. This particular nest extended to a depth of nearly 8 feet (7'8"). Calculations in Table 2.4 show that over 40 cubic inches of soil were probably moved to the soil surface by this colony and about 20 percent of this soil was brought up from depths greater than 6 feet. Assuming that the excavated nest was "typical" or "average" for the 104 nests on the 216-A-24 Crib, as much as 2.5 ft^3 of subsurface soils could have been brought to the surface by this species of insect.

In summary, plant and animal populations on the 216-A-24 Crib are typical for disturbed sites on the 200 Area plateau. The soil is sandy and has been covered with cobbles to reduce wind erosion. Stoniness of the soil surface probably has reduced the effectiveness of cover of cheatgrass (see Photograph 2, 3, and 4), restricted the abundance of ground-dwelling small mammal species, and encouraged deep penetration and conservation of the sparse annual precipitation in the area. This deep moisture may have contributed to the success of deep-rooted rabbitbrush shrubs on the crib.

TABLE 2.3. Taxonomic Composition, Density, and Biomass of Invertebrates associated with *Chrysothamnus nauseosus*[a]

Taxa	Density (Number)	Biomass (mg)
Coleoptera (beetles)		
Curculionidae	7	86.98
Homoptera (leafhoppers, aphids)		
Cicadellidae	10	11.98
Aphididae	2	0.39
Psyllidae	12	4.65
Hemiptera (true bugs)		
Reduviidae	1	3.87
Diptera (flies)		
Sciaridae	3	1.11
Chironomidae	1	0.04
Thysanoptera (thrips)	5	3.58
Lepidoptera (moths, butterflies)		
Noctuidae (larvae)	8	5.48
Acarina (mites)		
Caligonellidae	3	0.01
Unrecognized Prostigmata	2	0.02
Tetranychidae	1134	9.34
Hymenoptera (wasps, ants, bees)		
Chalcidoidea	1	0.03
TOTAL	1199	127.48

a. Values were obtained from a single plant (bush 438) and the litter beneath it, collected on May 1, 1975, and subjected to Berlese extraction.

TABLE 2.4. Harvester Ant (*Pogonomyrmex owyheei*) Nest Characteristics

Depth	Ant Numbers	Chamber Numbers	Soil Volume Excavated[b] Per Nest (in^3)	Soil Volume Excavated[b] Entire Crib[c] (in^3)
Mound	814	--[a]	--	--
Top 1 ft	350	--[a]	--	--
1-2 ft	293	26	11.1	1154
2-3 ft	217	13	9.2	957
3-4 ft	441	10	7.5	780
4-6 ft	225	10	5.4	562
6-8 ft	1835	9	9.1	946
TOTAL	4175	68	42.3	4399

a. The mound and upper foot of the nest was comprised of numerous interconnecting chambers and were not counted.
b. Volume of soil excavated was calculated by summation of volume calculations for chambers and tunnels. Nest excavation conducted on May 15, 1975 near 216-A-24 Crib.
c. Soil volume excavated for the entire crib area was calculated by multiplying soil volume excavated per nest times 104 nests in the study area.

3. DISTRIBUTION OF BETA-GAMMA-EMITTING RADIONUCLIDES ON THE CRIB SURFACE– FIELD STUDY

A Geiger-Müller survey instrument was used to monitor the area in late April 1975. Measurable amounts of radioactive materials appeared to be restricted to rabbitbrush plants and, in some cases, to the litter beneath them. Surface soils, insects, mice, rabbit fecal pellets, ant hills, cheatgrass, and sagebrush plants were found to be free of contamination readily measurable with a field instrument.

A detailed survey of shrubs on the second section of the crib was conducted by numbering all shrubs beginning at the western (upper) end of the crib and surveying each shrub separately. Since leaves, twigs, and branch tips had the highest levels of contamination, the measurements were taken by pressing the probe against 10-20 young twigs and leaves on each plant. Results of this field survey are given in Appendix II.

The upper section of Section II (see Figure 2.1) contained 73 shrubs (65 rabbitbrush and 8 sagebrush), none of which had radioactivity above background measurable with field survey instruments. The central section, including the mapped area and the land on either side, had 311 shrubs (310 rabbitbrush and 1 sagebrush). Of these, 198 were at background level (<200 cpm), 47 up to 10 times background (>200 cpm, <2000 cpm), and 66 were 2000 cpm or over (maximum 25,000 cpm). The lower section is 26 m long and contained 135 shrubs (131 rabbitbrush and 4 sagebrush). Of these, 93 were at background levels, 15 up to 10 times background, and 27 were over 2000 cpm (maximum 10,000 cpm). None of sagebrush plants contained contamination detectable in the field survey. The most contaminated shrubs on the section were numbers 139 and 221 which were about 125 times background (25,000 cpm). On the entire section 15 bushes contained 10,000 cpm or over. Of these, 12 bushes are included in the mapped area shown in Figure 3.1a. Circles represent individual bushes with the size of the circle varying with canopy size. Numbers in the circles in Figure 3.1a refer to the number of the bush. Figure 3.1b shows the same map with the number in the center of the circle being the level of radioactivity in the shrub (see Appendix II) in thousands of counts per minute. Plants having no more than background levels are indicated as blank circles or are shown with a "B". Generally, plants with high levels were surrounded by plants with intermediate levels, but there were instances where adjacent shrubs differed by orders of magnitude (Photographs 5 and 6).

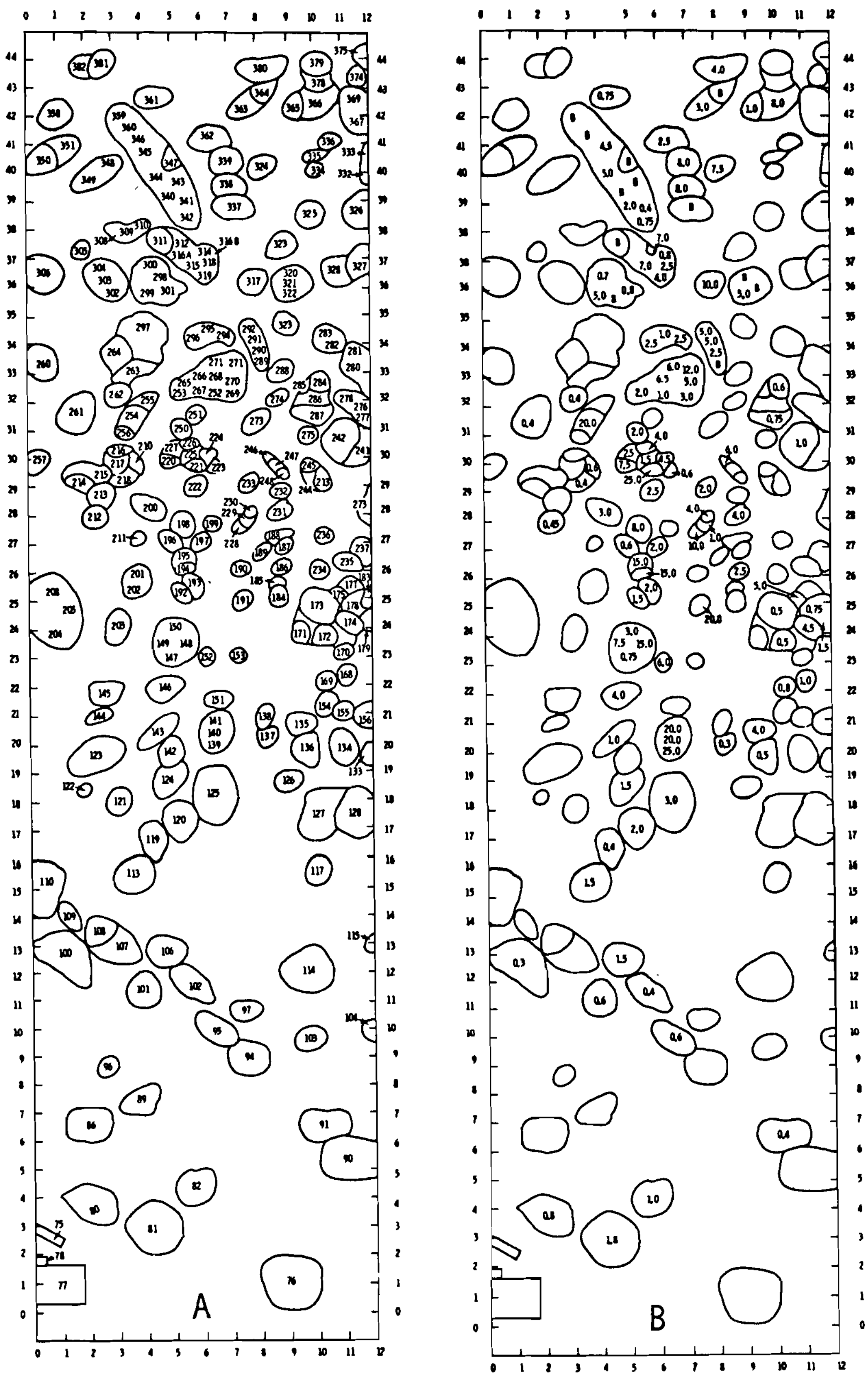


FIGURE 3.1. Location and Levels of Radioactivity in Shrubs on the Study Area. The map on the left shows the location, canopy size, and number assigned to the bushes. The map on the right shows the radioactivity associated with the canopy of each shrub in the thousands of counts per minute. Shrubs at background levels (<200 cpm) are shown as blank except in a few cases where they are designated with a "B". Scale numbers are distances in meters.

4. RADIONUCLIDES BELOW THE SURFACE — EXCAVATION RESULTS

Three backhoe excavations were made into the crib. These will be referred to as A, B, and C. Excavations A and B were in the lower end of Sections I and II, respectively, about 10 feet west of the green risers which mark ends of crib sections. Both A and B extended down to the gravel layer. They were dug to determine whether soils above the gravel layer contained radioactive materials and to observe the condition of the polyethylene sheet (see Figure 1.1) after 17 years of burial in the crib. Excavation C was made about 18 feet west of the green riser at the lower end of Section II in order to obtain two rabbitbrush root systems for radiochemical analysis.

None of three excavations showed that soils contained amounts of radioactivity detectable with a field instrument. Rabbitbrush roots did occasionally show some activity. Table 4.1 shows the ^{137}Cs levels in samples of soils and roots collected at various depths from excavations B and C.

Although soils above the gravel layers contained no detectable contamination, the gravel layers themselves did have considerable amounts. In both Section I and Section II, gravels from above the drainpipe (see Figure 1.1) registered about 7500 cpm on the field monitoring instrument. Gravel in Section I was damp and was covered with sandy soil; that in Section II appeared dry, but contained obvious rabbitbrush roots. Remnants of a polyethylene sheet were found mixed with the soil in Section I; there was no evidence of any polyethylene sheet in Section II. Disintegration of the polyethylene sheet in Section I was probably brought about from the gamma radiation from materials in the gravel below the sheet, but other weathering and aging agents are not necessarily ruled out.

A sample of the soil-gravel mixture was removed from Section I and analyzed for ^{137}Cs. Results are presented in Table 4.2. Pieces of gravel which had been washed and wiped contained about 10 times the ^{137}Cs on a dry weight basis as did soil from the same sample. This was somewhat unexpected and implies that cesium migrated into the matrix of the gravel. However, it is possible that the activity could have been removed if the surface of the gravel had been polished or acid washed. A sample of this soil was submitted for gamma energy analysis and ^{90}Sr analysis to U.S. Testing. The gamma scan showed 5.21 nCi ^{137}Cs/gDW which agrees favorably with the value of 3.0 nCi/gDW reported in Table 4-2 and obtained on a parallel sample by counting on a single channel analyzer. The scan also showed a trace of ^{134}Cs and ^{40}K but no significant ^{60}Co. The soil also had 0.0259 nCi ^{90}Sr/gDW.

Root systems of two rabbitbrush plants were excavated. One of these (Table 4.3) had 320 nCi ^{137}Cs/gDW of leaves and the second (Table 4.4) had 2.3 nCi ^{137}Cs/gDW leaves. Table 4.3 shows that there is an increase in radiocesium concentration in both wood and bark for the taproots and lateral

TABLE 4.1. Radiocesium in Soils and Rabbitbrush Roots at Various Depths in the 216-A-24 Crib. Soil values are an average from two samples collected about one meter apart from the face of the excavation. Roots, collected from along the face, were pooled into a single sample for each depth.

Depth (cm)	^{137}Cs (nCi/gDW) Soil	Roots
Excavation B		
50	BDL*	21
100	BDL	12
150	BDL	160
200	BDL	57
Excavation C		
50	BDL	4.1
100	BDL	0.71
150	BDL	9.8

*BDL = Below Detection Limits, ∿ 0.1 nCi/sample.

TABLE 4.2. Cesium-137 in Gravel and Soil Collected from the Bottom of Section I of the 216-A-24 Crib. Gravel pieces were rinsed with distilled water and wiped to remove particles of sand and silt adhering to the surface.

^{137}Cs (nCi/gDW) Washed Gravel		Soil
32.9		
1.56		5.89
45.2		0.136
13.7		
83.5		
35	(Average)	3.0

roots with depth. This trend is also apparent in data for the taproot in Table 4.4, but not for lateral roots. Nevertheless, the data show that the source of activity is deep in the profile. Cesium is probably readily exchanged between bark and wood just as potassium is. The gradient of cesium-137 in the bark with depth in Table 4.3 indicates that it is being exchanged with the wood. The other possible source would be contaminated leaves which might export cesium along with photosynthates translocated to the roots.

TABLE 4.3. Cesium-137 in the Wood and Bark of the Taproot and Lateral Roots of a Rabbitbrush Root System Collected from Excavation in Section II of the 216-A-24 Crib. Leaves of this plant (434) showed 5000 cpm in the field survey and 320 nCi ^{137}Cs per gDW.

^{137}Cs (nCi/gDW)

Depth (cm)	Taproot Wood	Taproot Bark	Depth (cm)	Lateral Roots Wood	Lateral Roots Bark
			12	18	33
16-48	40	96	16	9.3	20
			48	22	53
57-83	44	160			
112-158	101	270			
			163	45	170
			181	52	150
187-224	93	250			
			224	93	250

TABLE 4.4. Cesium-137 in the Wood and Bark of the Taproot and Lateral Roots of a Rabbitbrush Root System Collected from Excavation in Section II of the 216-A-24 Crib. Leaves of this plant (446) showed <200 cpm (background) in the field survey and 2.3 nCi ^{137}Cs/gDW.

^{137}Cs (nCi/gDW)

Depth (cm)	Taproot Wood	Taproot Bark	Depth (cm)	Lateral Roots Wood	Lateral Roots Bark
50-60	0.59	1.6	75	2.0	5.8
75-87	0.85	3.0	87	0.58	2.4
			87	0.92	3.9

5. RADIONUCLIDES IN SELECTED SOIL, PLANT, AND ANIMAL SAMPLES

A number of biological, litter, and soil samples were taken from Section II of the Crib for the following purposes:

- to measure radionuclides in rabbitbrush leaves along the center of the Crib to determine whether the same nuclides are involved over the length of the Crib;
- to determine the location within the plant of the greatest concentration of radioactivity;
- to determine the potential for contamination of surface soils through annual litterfall beneath rabbitbrush plants; and
- to determine whether animals on the Crib contain measurable quantities of radionuclides from consumption of contaminated leaves or other materials.

To accomplish the first of these objectives, leaves from 32 plants in the center of the mapped area of the Crib were collected along a transect chosen to be directly over the buried drainpipe. These leaves were submitted for gamma energy analyses and for ^{90}Sr analyses. Results are given in Appendix III.

This table shows that the principal radionuclide involved is ^{137}Cs which has an average value of 145 nCi/gDW for the 32 samples along the transect. Actual values range from "not detectable" to 891 nCi/gDW. Throughout the length of the transect there were samples which showed detectable amounts of ^{144}Ce, ^{106}Ru, ^{95}Zr, and ^{54}Mn, but concentrations were so low when compared to levels of ^{137}Cs that precise measurement with the counting and spectrum stripping techniques used was impractical.

Levels of ^{90}Sr were nearly three orders of magnitude less than those for ^{137}Cs. The average value over the transect was 0.316 nCi ^{90}Sr/gDW. Generally speaking, samples with high levels of ^{137}Cs have high levels of ^{90}Sr. The average value for the ratio of cesium to strontium concentration is 1500. The same radionuclides occur along the length of the transect.

To accomplish the second objective, a single shrub (number 191, which showed 20,000 cpm in the field survey) was removed to the laboratory and dissected into shoot parts (leaves, twigs, bark, wood) and roots (bark and wood). Results are given in Table 5.1 for radiocesium concentrations in these plant parts. Shoots show higher concentrations than roots and the highest concentrations are in the leaves.

TABLE 5.1. Radiocesium in Parts of a Contaminated Rabbitbrush Plant from the 216-A-24 Crib.

	^{137}Cs(nCi/gDW) Branch 1	^{137}Cs(nCi/gDW) Branch 2
Shoots		
Leaves	220	280
Twigs	63	58
Bark	54	73
Wood (upper)	17	19
Wood (lower)	25	33
Roots		
Bark	6.5	1.6
Wood	39	8.5

To accomplish the third objective, six rabbitbrush plants showing different levels of activity were selected. For these six shrubs, samples were taken of leaves, cheatgrass growing beneath the canopy, litter beneath the canopy, the upper cm of mineral soil beneath the litter, soil at the 15 cm depth, and rabbitbrush roots at the 15 cm depth. Also samples of cheatgrass and underlying surface soils as well as bare soils between rabbitbrush plants were collected. These samples were counted for ^{137}Cs content. Results are shown in Table 5.2.

In general, plants with highest levels of ^{137}Cs in this year's leaves had the highest levels of ^{137}Cs in litter, cheatgrass, surface soils, and rabbitbrush roots at the 15 cm depth. In no case was there significant activity in soil samples taken at the 15 cm depth.

Cheatgrass samples taken from between shrubs were almost invariably less contaminated than were similar samples taken from beneath shrub canopies. Samples of the upper cm of soil taken in unvegetated areas (bare soil) and under uncontaminated rabbitbrush canopies were not contaminated. However, detectable levels were found in surface soils taken from beneath the cheatgrass swards sampled between shrubs even though the newly grown cheatgrass leaves were not notably contaminated. Apparently, cheatgrass swards have captured some wind-borne materials from nearby contaminated plants and from worldwide fallout causing some ^{137}Cs to accumulate in the upper cm of soil.

TABLE 5.2. Cesium-137 in Plant and Soil Samples

	^{137}Cs (nCi/gDW)					
Shrub Number	Rabbitbrush Leaves	Litter	Cheatgrass	Surface Soil	Soil at 15 cm	Rabbitbrush Roots at 15 cm
			Beneath Canopies			
94	0.013	0.294	0.833	0.0625	BDL	BDL
344	0.036	2.46	0.485	0.0232	BDL	BDL
143	14	3.24	0.240	0.231	BDL	2.46
148	62	30.9	2.38	0.793	BDL	68.2
342	890	3.69	BDL*	0.392	BDL	0.903
221	520	47.7	3.62	2.24	BDL	41.7
			Between Canopies			
Cheatgrass (between shrubs)			0.117	1.06	BDL	
Cheatgrass (between shrubs)			BDL	0.350	BDL	
Bare soil (between shrubs)				0.0793		
Bare soil (between shrubs)				0.0833		

*BDL = Below detection limits, ~0.1 nCi/sample.

To accomplish the fourth objective, a number of animal samples were collected. These included invertebrates associated with rabbitbrush plants and those caught in pitfall traps and by hand, seven pocket mice, and all of the rabbit fecal pellets from the west half of the mapped area (12 x 22 meters). The fecal pellets were ground and composited into a single large sample which was subsequently subsampled for radiochemical analysis.

Radiocesium concentrations for insects associated with rabbitbrush plants were higher than those collected either by hand or from pitfall traps (Table 5.3). The average value for the eight shrub-associated species was 16.3 nCi/gDW, ranging from 1.9 to 71.5 nCi/gDW.

Of the seven mice analyzed, two had ^{137}Cs levels significantly above background (Table 5.4). These two mice were dissected into hide, muscle and skeleton, and gut and these components analyzed separately. Results in Table 5.5 indicate that 12.3% of the ^{137}Cs was in the hide, 69.5% in the muscle and bone, and 18.2% in the gut.

Rabbit pellets had an average value of 0.21 nCi ^{137}Cs/gDW. Since rabbits have rather large ranges, the source of the cesium in these pellets is uncertain.

TABLE 5.3. Concentrations of ^{137}Cs for Invertebrates Collected on the 216-A-24 Crib

Taxa	Lifestage	Food Habits	Biomass (mg)	Body Burden (nCi)	Concentration (nCi ^{137}Cs/gDW)
Invertebrates Associated with Rabbitbrush					
Acarina					
Tetranynchidae	Adult & Nymph	Plant Tissue	2.47	0.177	71.5
Lepidoptera					
Noctuidae	Larvae	Plant Tissue	4.52	0.0547	12.1
Homoptera					
Psyllidae	Adult	Sap Sucking			
Aphididae	Adult	Sap Sucking	16.76	0.0404	2.4
Cicidellidae	Adult				
Diptera & Hymenoptera					
Sciaridae	Adult	Pollen			
Chironomidae	Adult	Pollen	1.27	0.0024	1.9
Chalcidoidea	Adult	Pollen			
Alcohol (Sample of alcohol used in extraction)				0.0978	
Coleoptera					
Curculionidae	Adult	Plant Tissue	72.54	1.576	21.7
Acarina					
Caligonellidae	Adult	Predator	3.11	0.0091	2.9
Unident. Prostigmate	Adult	Predator			
Hemiptera					
Reduviidae	Adult	Predator	3.87	0.0589	15.2
Thysanoptera	Adult	Plant Tissue	1.20	0.0027	2.3
Invertebrates Collected from Pitfall Traps					
Coleoptera					
Curculionidae	Adult	Plant Tissue	132.1	0.8027	6.1
Tenebrionidae	Adult	Litter	1303.0	0.0592	0.05
Tenebrionidae	Adult	Litter	439.8	0.0544	0.1
Hand-Collected Invertebrates					
Diptera					
Asilidae	Adult	Predator	15.6	0.0267	1.7
Orthoptera					
Acrididae	Adult	Plant Tissue	114.5	0.0021	0.02
Formicidae	Adult	Seeds	23.9	0.0081	0.3

TABLE 5.4. Cesium-137 in Pocket Mice Collected on the 216-A-24 Crib. Detection limit of the system used is about 0.03 nCi.

Sample Number	Net cpm	nCi ^{137}Cs	SD
75KP0010	3.09	0.0121	0.0148
75KP0011	(-0.29)	0.0	0.0148
75KP0012*	156.0	0.612	0.0163
75KP0013	(-4.66)	0.0	0.0146
75KP0014	(-3.44)	0.0	0.0146
75KP0015	0.75	0.00294	0.0148
75KP0016*	608.0	2.38	0.0201

*Statistically significant

TABLE 5.5. Radiocesium Levels in Dissected Components of Two Contaminated Pocket Mice Captured on the 216-A-24 Crib

	Net cpm	nCi ^{137}Cs	Standard Deviation	% of Total Body Burden
75KP0012				
Hide	15.2	0.0595	0.0148	9.9
Muscle and skeleton	111.3	0.4357	0.0158	72.6
Gut	26.7	0.1047	0.0149	17.5
		Σ = 0.5999 nCi		
75KP0016				
Hide	88.7	0.3448	0.0167	14.8
Muscle and skeleton	399.1	1.5518	0.0380	66.5
Gut	112.7	0.4382	0.0318	18.7
		Σ = 2.3348 nCi		

DISCUSSION OF RESULTS

Radioactivity associated with rabbitbrush plants on the 216-A-24 Crib is primarily ^{137}Cs. Leaves contained higher concentrations of ^{137}Cs than other plant parts. Concentrations of ^{137}Cs in leaves averaged 145 nCi/gDW and those for ^{90}Sr averaged 0.316 nCi/gDW. Sand from the gravel layer in the first section of the Crib had 3.0 nCi ^{137}Cs/gDW and 0.0259 nCi ^{90}Sr/gDW. Using these values for substrate and leaf concentrations, a concentration factor (c.f.) of 48.7 for ^{137}Cs and 12.2 for ^{90}Sr can be calculated.

Routson (Routson, 1975) found that tumbleweed seedlings grown for 12 weeks in pots in growth chamber experiments have concentration factors of 0.053 for ^{137}Cs and 19 for ^{90}Sr. Thus, the values calculated from data in this report are in agreement with Routson's values for ^{90}Sr, but are three orders of magnitude higher than his values for ^{137}Cs. Of course, the two plant species may have different cesium affinities; there are no C.F. values available for rabbitbrush. Also, it is possible that roots may have penetrated deeper in the profile than the level of excavation and sampling. At deeper levels, ^{137}Cs content would probably be much higher than that of the material sampled from above the drainpipe so that concentration factors calculated would be considerably reduced.

While the facility was operating, water percolated downward from the drainpipe and carried cesium and strontium downward in the profile. Because of differences in behavior of these two radionuclides in soil, we would expect radiocesium to be held in the root zone to a greater extent than strontium. Thus, although cesium is discriminated against by most plants, the relative concentration of ^{137}Cs in the root zone may be sufficiently great to cause cesium concentrations in leaves to equal or exceed the strontium levels.

The fact that there is considerable activity associated with the gravel is worth noting. The cesium may be taken up into such components of the gravel as mica. It is not known whether plants are absorbing cesium from the gravel or from soil between gravel pieces.

The distribution of ^{137}Cs in the bark and wood of these rabbitbrush plants is similar to distributions found for potassium in willow stems (Stout and Hoagland, 1939). In willow, ^{42}K readily exchanged between wood and bark but did not move readily in the phloem (bark). In the present investigation, concentrations and vertical gradients of ^{137}Cs in the bark were related to the values in the adjacent wood. Assuming that cesium does not move readily in phloem of rabbitbrush plants, one would expect it to build up in the leaves over the growing season so that values of the C.F. would be seasonally dependent.

We do not know why the population of rabbitbrush is most dense and shows the highest levels of activity on the second section of the Crib. It appears, though, that the high level of activity results from the fact that the average rooting depth is greater in this dense stand than it is on other parts of the Crib.

The environmental factor most probably responsible for the dense and presumably deep-rooted stand is a greater and deeper supply of soil moisture. Several characteristics of the Crib surface are favorable for water accumulation. Chief among these are the presence on the surface of large cobbles which both increase runoff into depressions and decrease plant cover and the presence of unvegetated roads. A complete plant cover would more effectively use annual precipitation through root uptake and plant transpiration. The presence of channels open to the surface in certain dead ant nests could carry water to depth without saturating upper layers and thus contribute to deep supplies of moisture. The densest stand of rabbitbrush coincides with a depression in the landscape caused in part by a hill to the south. If rainfall and blowing snow are concentrated in this depression, then moisture would penetrate deeper in the profile and would encourage deep rooting of rabbitbrush plants.

This Crib has provided a unique opportunity to examine some aspects of radiocesium behavior in the 200 Area plateau. Data on food web transfers from mature leaves contaminated by plant uptake in the field are rare. Such data are expensive to obtain in the laboratory because of the long time required for producing mature plants. It would be valuable to sample during the summer to determine how plant uptake factors vary seasonally and to conduct some experiments on food web transfers of cesium. This site is especially important because the levels of interfering radionuclides are so low that ^{137}Cs can be determined inexpensively without having to account for other isotopes such as ^{90}Sr.

RECOMMENDATIONS

Rabbitbrush plants need to be eradicated from the Crib surface. The radioactive material from the central 12 meters of the second section probably should be removed for disposal. This material includes rabbitbrush plants, litter, and cheatgrass. The surface centimeter of soil could be scraped off the central 12 meters, but this may not be necessary since activity levels are quite low (see Table 5.2). Subsurface soils do not need to be removed. Rabbitbrush plants outside the central strip could be burned since they contain no detectable activity.

In order to prevent the sprouting of rabbitbrush from buds on the stumps, it would be advisable to spray the plants with a herbicide prior to the eradication. This will kill the buds which would produce sprouts.

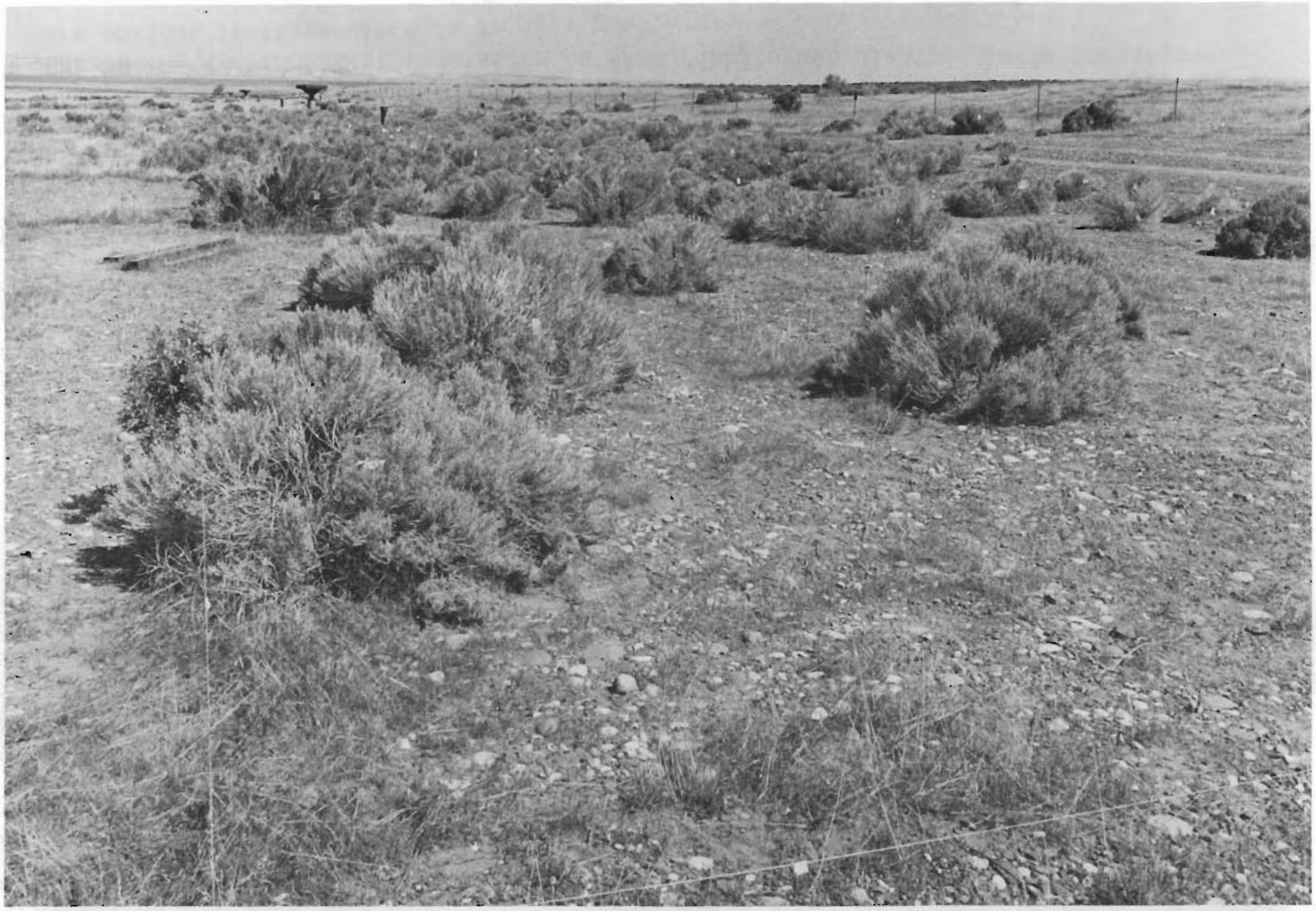
Restoration of the surface can be made by scraping the cobble layer from the surface and replacing it with a one-foot layer of clean soil. The depression in the center of the Crib can be filled in by bulldozing onto the Crib surface the hill of unused backfill materials located to the south. Clean surface soil is also available from the area to the south. This filling and revegation could most effectively be done in October when natural rainfall would help prevent wind erosion and would promote germination of cheatgrass seed. A mulch of straw and bentonite and a dressing of fertilizer on the surface soil would be helpful in establishing cheatgrass during the first year. The stand should maintain itself after it has become established. Finally, an effort should be made to keep road traffic off of the new surface so that the plants can maintain a good cover.

We believe that there would be an advantage in permitting this Crib to be used as a study area prior to restoration (see previous page).

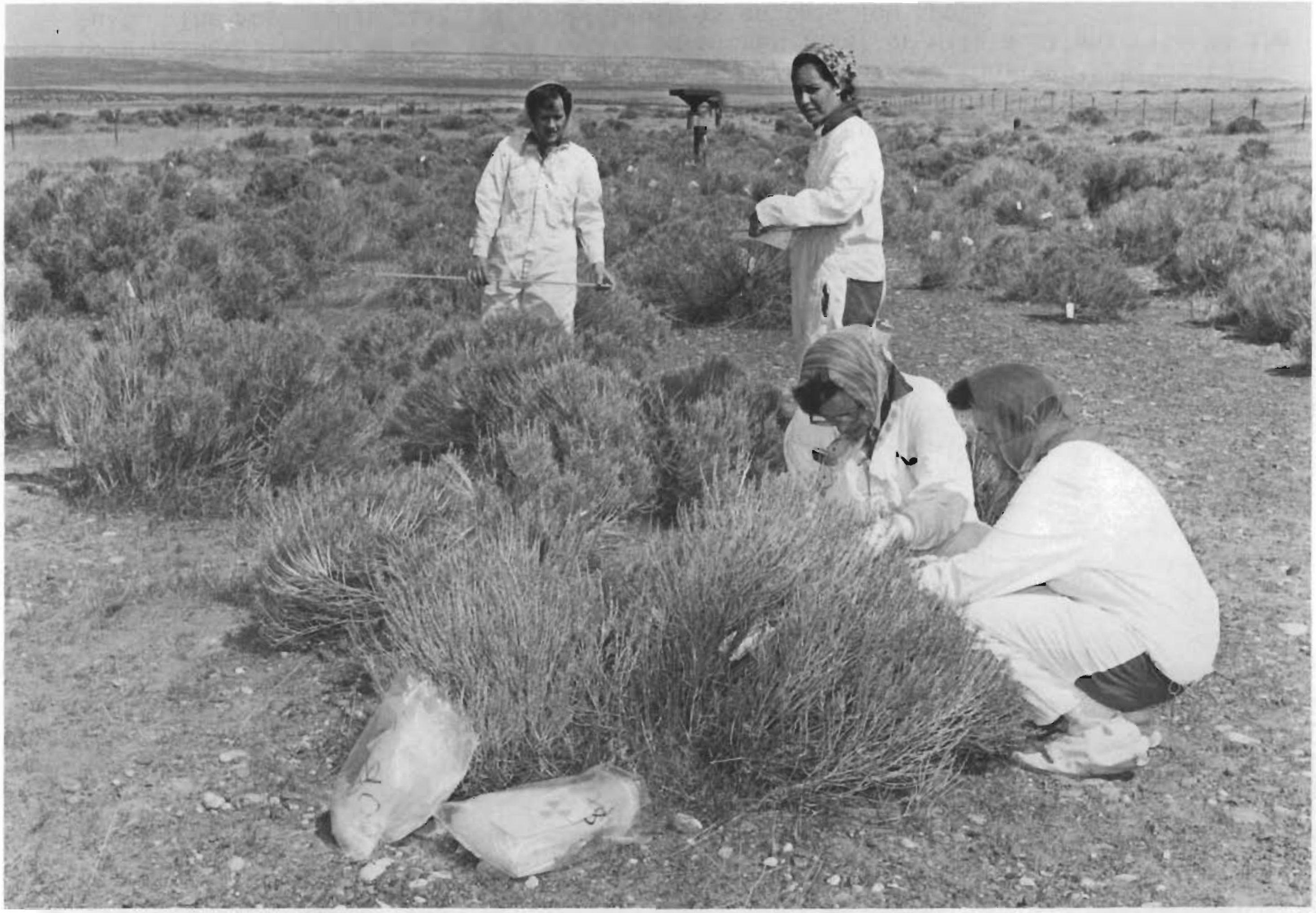
PHOTOGRAPHS

PHOTOGRAPH 1. A view of Section II of the 216-A-24 crib. The photograph was taken from the upper green vent (Fig. 2.1). The rabbitbrush is sparse in the foreground. Shrub density increases markedly below the upper monitoring well which is the standpipe in front of the nearest person. These shrubs appear to be in a slight depression on the crib surface. The land rises slightly to the west and south and is comparatively level to the east and north. Two unvegetated roadways and large cobbles appear in the surface soils in the foreground.

PHOTOGRAPH 2. A view of the mapped area in the central section of the crib. Features include the lower monitoring well which ends the mapped section and the lower green vent which designates the end of the second section of the crib. The string and tag in the foreground designate the upper end of the mapped area. Notice that cheatgrass grows poorly where cobbles predominate on the soil surface.



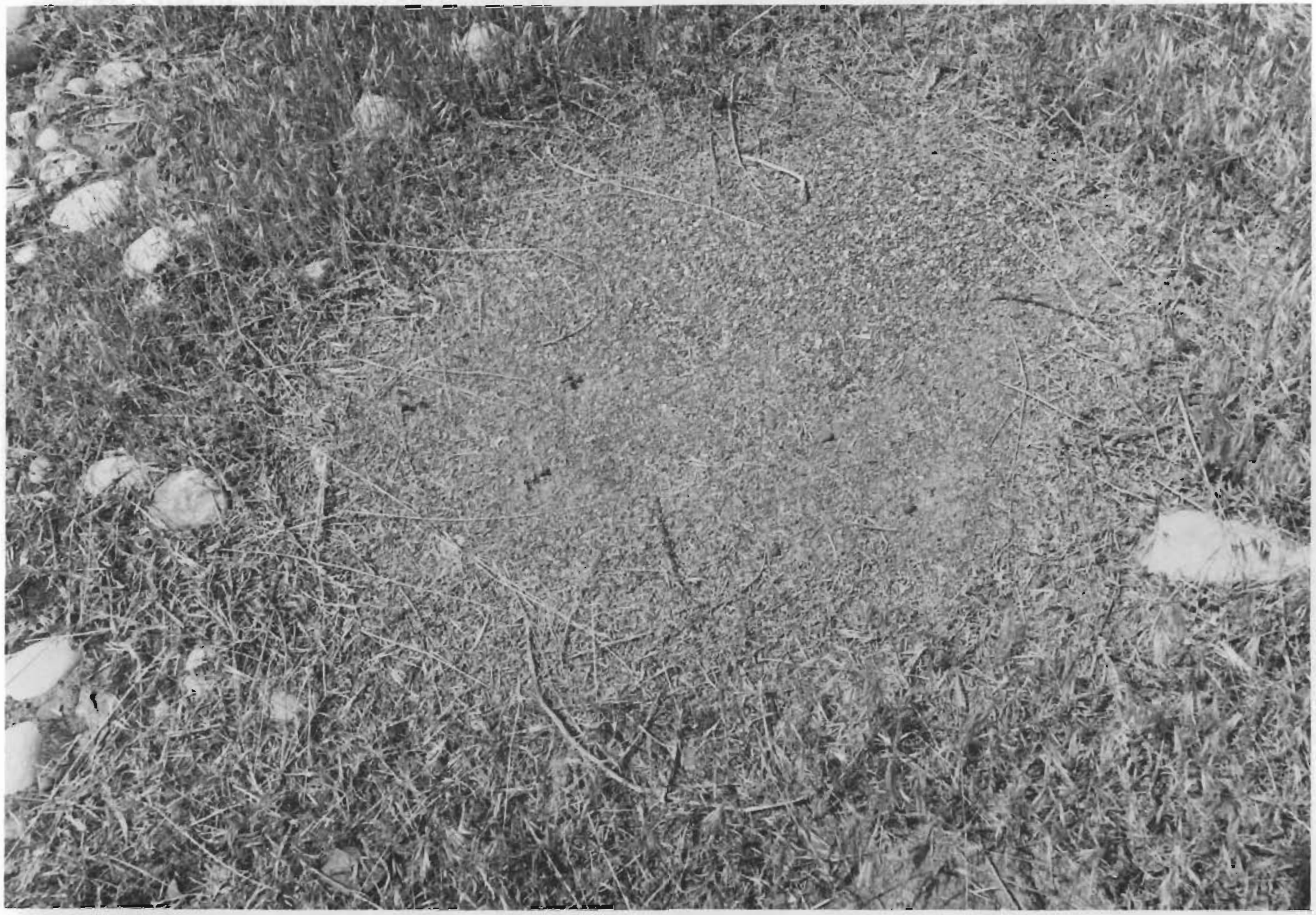
PHOTOGRAPH 3. A view from the northwest corner of the mapped area. Strings designate map boundaries. Notice the rising topography to the right (south) and the roadway which passes along the southern edge of the exclusion area. The land appears to rise rather steeply to the right and to be either level or with a slight rise to the left. The most dense stand of rabbitbrush is in this low spot.



PHOTOGRAPH 4. A view down the central transect of the mapped area which ends at the lower monitoring well (the plain standpipe midway between the two standing persons). Notice the sparseness of vegetation between rabbitbrush plants. Large cobblestones are obvious in the surface soil.

PHOTOGRAPH 5. An example of the close juxtaposition of radioactive and "background" shrubs. Shrub 174, which showed 4500 cpm in the field survey, is surrounded by shrubs with very little activity. For example, to the left is a tag on shrub 173 which had 500 cpm and in the foreground is a shrub which surveyed at <200 cpm.

PHOTOGRAPH 6. An example of the apparent randomness of the occurrence of radioactivity in shrubs. Shrub number 345 showed 5000 cpm in the field survey and shrub 346, which is to the right of 345, showed 4500 cpm. All of the surrounding bushes were at background.



PHOTOGRAPH 7. A Harvester Ant nest. Notice the absence of plant cover on the ant nest. There were 104 ant nests on the 216-A-24 crib. Excavations have shown that nests of these insects can extend as deep as 7 feet 8 inches in the area adjacent to the crib.

PHOTOGRAPH 8. The woody roots of a rabbitbrush plant growing south of the second section of the 216-A-24 crib. Notice the layer of surface material. It is backfill material from the construction of the crib. This backfill material covers the original soil profile which is a deep uniform sandy material.

PHOTOGRAPH 9. Gravel from an excavation of the lower end of section II of the crib. Notice the obvious plant roots in the gravel. This shovel full of gravel registered 7500 cpm on a G-M probe. Soils above the gravel layer surveyed at less than 200 cpm. The gravel layer was 8 feet below the surface.

LITERATURE CITED

Anderson, J. D. 1975. Radioactive Liquid Wastes Discharged to Ground in the 200 Areas during 1974. ARH-3093 4Q.

Cline, J. F., D. W. Uresk, and W. H. Rickard. 1975. Characterization of Plant Communities adjacent to the B-C Cribs Controlled Area and REDOX Pond Areas on the 200 Area Plateau. BNWL-1916.

Lundgren, L. L. 1970. 200 East and North Areas Radioactive Liquid Waste Disposal Sites. ARH-1562.

Routson, R. C. 1975. The Effect of Soil Concentration on the Tumbleweed Uptake of ^{90}Sr and ^{137}Cs from a Burbank Sand. BNWL-1905.

Stout, P. R. and D. R. Hoagland. 1939. Amer. J. Bot. 26:320-324.

APPENDICES

APPENDIX I

Plant age and size as related to radioactivity in leaf tips. Plants were aged by counting annual rings on stem sections. Canopy volume was calculated from the formula, $(2\pi/3)[(h + 0.5\ w + 0.5\ l)/3]^3$ on the assumption that the canopy is a hemisphere.

Shrub Number	Canopy Size				Age (yr)	Radioactivity (cpm)
	h (cm)	w (cm)	l (cm)	vol. (m^3)		
94	77	150	100	0.64	10	<200
142	74	105	70	0.33	9	<200
343(dead)	56	76	56	0.14	(7)	<200
344	55	42	34	0.06	8	<200
102	47	124	100	0.31	10	400
118	74	120	100	0.48	11	400
119	75	113	105	0.49	12	400
95	68	120	110	0.47	9	600
196	53	73	40	0.10	10	600
147	47	60	30	0.06	9	750
342	68	115	56	0.28	12	750
143	67	80	72	0.23	9	1000
295	74	80	68	0.25	11	1000
106	67	100	80	0.30	6	1500
124	71	115	86	0.39	11	1500
120	88	115	113	0.65	9	2000
192	56	58	54	0.11	10	2000
341	75	---	---	----	10	2000
222	73	84	80	0.29	10	2500
150	56	80	50	0.14	7	3000
269	47	50	48	0.07	9	3000
316	88	90	62	0.34	8	4000
224	40	67	46	0.07	9	4500
270	60	50	40	0.09	10	5000
268	61	53	50	0.11	11	6500
314	70	80	52	0.19	9	7000
149	62	100	90	0.30	9	7500
198	68	94	60	0.24	9	8000
148	49	67	50	0.10	8	15000
194	50	65	35	0.08	10	15000
195	60	86	86	0.24	10	15000
221	59	58	70	0.14	10	25000

APPENDIX II

Levels of radioactivity in numbered shrubs on Section II of the 216-A-24 Crib. Numbering began at the western end of the crib. Numbers 1, 3, 14, 42, 44, 46, 51, 61, 78, 492, 502, 510, and 512 were sagebrush; all others were rabbitbrush. Radioactivity measured as counts per minute with a G-M portable meter.

Plant Number	Counts Per Minute	Plant Number	Counts Per Minute
1	<200	26	<200
2	<200	27	<200
3	<200	28	<200
4	<200	29	<200
5	<200	30	<200
6	<200	31	<200
7	<200	32	<200
8	<200	33	<200
9	<200	34	<200
10	<200	35	<200
11	<200	36	<200
12	<200	37	<200
13	<200	38	<200
14	<200	39	<200
15	<200	40	<200
16	<200	41	<200
17	<200	42	<200
18	<200	43	<200
19	<200	44	<200
20	<200	45	<200
21	<200	46	<200
22	<200	47	<200
23	<200	48	<200
24	<200	49	<200
25	<200	50	<200

Plant Number	Counts per Minutes	Plant Number	Counts per Minute
51	<200	86	<200
52	<200	87	<200
53	<200	88	<200
54	<200	89	<200
55	<200	90	<200
56	<200	91	400
57	<200	92	<200
58	<200	93	<200
59	<200	94	<200
60	<200	95	600
61	<200	96	<200
62	<200	97	<200
63	<200	98	<200
64	<200	99	<200
65	<200	100	300
66	<200	101	600
67	<200	102	400
68	<200	103	<200
69	<200	104	<200
70	<200	105	<200
71	<200	106	1500
72	<200	107	<200
73	<200	108	<200
74	<200	109	<200
75	<200	110	<200
76	<200	111	<200
77	<200	112	<200
78	<200	113	1500
79	<200	114	<200
80	800	115	<200
81	1800	116	<200
82	1000	117	<200
83	<200	118	400
84	<200	119	400
85	<200	120	2000

Plant Number	Counts per Minute	Plant Number	Counts per Minute
121	<200	156	<200
122	<200	157	<200
123	<200	158	<200
124	1500	159	<200
125	3000	160	<200
126	<200	161	<200
127	<200	162	<200
128	<200	163	<200
129	<200	164	<200
130	<200	165	<200
131	<200	166	<200
132	<200	167	<200
133	<200	168	1000
134	<200	169	800
135	4000	170	<200
136	500	171	<200
137	300	172	500
138	<200	173	500
139	25,000	174	4500
140	20,000	175	5000
141	20,000	176	<200
142	<200	177	<200
143	1000	178	750
144	<200	179	1500
145	<200	180	<200
146	4000	181	<200
147	750	182	<200
148	15,000	183	<200
149	7500	184	<200
150	3000	185	<200
151	<200	186	2500
152	6000	187	<200
153	<200	188	<200
154	<200	189	<200
155	<200	190	<200

Plant Number	Counts per Minute	Plant Number	Counts per Minute
191	20,000	226	4000
192	2000	227	2500
193	1500	228	10,000
194	15,000	229	1000
195	15,000	230	4000
196	600	231	4000
197	2000	232	<200
198	8000	233	2000
199	<200	234	<200
200	3000	235	<200
201	<200	236	<200
202	<200	237	<200
203	<200	238	<200
204	<200	239	<200
205	<200	240	<200
206	<200	241	<200
207	<200	242	1000
208	<200	243	<200
209	<200	244	<200
210	<200	245	<200
211	<200	246	6000
212	450	247	<200
213	<200	248	<200
214	<200	249	3500
215	<200	250	2000
216	<200	251	<200
217	<200	252	1000
218	400	253	<200
219	600	254	20,000
220	7500	255	<200
221	25,000	256	<200
222	2500	257	<200
223	600	258	<200
224	4500	259	<200
225	1500	260	<200

Plant Numbers	Counts per Minute	Plant Numbers	Counts per Minute
261	400	291	5000
262	400	292	5000
263	<200	293	6500
264	<200	294	2500
265	2200	295	1000
266	<200	296	2500
267	2000	297	<200
268	6500	298	800
269	3000	299	5000
270	5000	300	700
271	3000	301	<200
271A	6000	302	<200
271B	12,000	303	<200
272	6000	304	<200
273	<200	305	<200
274	<200	306	<200
275	<200	307	<200
276	<200	308	<200
277	<200	309	<200
278	<200	310	<200
279	<200	311	<200
280	<200	312	<200
281	<200	313	600
282	<200	314	7000
283	<200	315	7000
284	600	316	4000
285	<200	317	10,000
286	<200	318	800
287	750	319	2500
288	<200	320	5000
289	<200	321	<200
290	2500	322	<200

Plant Numbers	Counts per Minute	Plants Numbers	Counts per Minute
323	<200	356	<200
324	7500	357	<200
325	<200	358	<200
326	<200	359	<200
327	<200	360	<200
328	<200	361	750
329	<200	362	2500
330	<200	363	3000
331	<200	364	<200
332	<200	365	1000
333	<200	366	8000
334	<200	367	<200
335	<200	368	<200
336	<200	369	<200
337	<200	370	<200
338	8000	371	<200
339	8000	372	<200
340	400	373	<200
341	2000	374	<200
342	750	375	<200
343	<200	376	800
344	<200	377	<200
345	5000	378	<200
346	4500	379	<200
347	<200	380	4000
348	<200	381	<200
349	<200	382	<200
350	<200	383	500
351	<200	384	<200
352	<200	385	<200
353	<200	386	<200
354	<200	387	<200
355	<200	388	<200

Plants Numbers	Counts per Minute	Plants Numbers	Counts per Minute
389	<200	421	4000
390	550	422	<200
391	800	423	<200
392	<200	424	<200
393	<200	425	1000
394	<200	426	<200
395	5500	427	2500
396	<200	428	<200
397	<200	429	<200
398	<200	430	<200
399	<200	431	3500
400	<200	432	800
401	<200	433	10,000
402	<200	434	5000
403	<200	435	10,000
404	<200	436	8000
405	<200	437	8000
406	<200	438	10,000
407	<200	439	<200
408	<200	440	1000
409	<200	441	<200
410	5000	442	7000
411	<200	443	<200
412	700	444	4500
413	<200	445	7000
414	<200	446	<200
415	<200	447	<200
416	<200	448	<200
417	4500	449	<200
418	6000	450	<200
419	1000	451	<200
420	<200	452	<200

Plant Numbers	Counts per Minute	Plant Numbers	Counts per Minute
453	2000	486	<200
454	3000	487	<200
455	800	488	<200
456	<200	489	<200
457	6000	490	<200
458	<200	491	<200
459	<200	492	<200
460	1000	493	<200
461	<200	494	<200
462	<200	495	<200
463	<200	496	<200
464	<200	497	<200
465	<200	498	<200
466	<200	499	<200
467	<200	500	<200
468	<200	501	<200
469	<200	502	<200
470	1000	503	1500
471	2000	504	4500
472	<200	505	6000
473	<200	506	6000
474	1000	507	8000
475	<200	508	<200
476	<200	509	4000
477	<200	510	<200
478	<200	511	<200
479	<200	512	<200
480	<200	513	1000
481	<200	514	3000
482	<200	515	6000
483	<200	516	<200
484	1000	517	<200
485	<200		

APPENDIX III

Radionuclides in leaves of plants growing along the central transect of Section II of the 216-A-24 Crib, strontium was determined by chemical precipitation followed by counting on a low beta proportional counter. Other radionuclides were determined by gamma energy analysis of scans obtained with a NaI crystal. Blanks are shown where standard errors were greater than the calculated value.

Plant Number	^{90}Sr nCi/gDW	^{137}Cs nCi/gDW	^{144}Ce nCi/gDW	^{106}Ru nCi/gDW	^{95}Zr nCi/gDW	^{54}Mn nCi/gDW
94	0.0035	--	--	--	--	--
95	0.0666	27.2	3.84	--	0.2	0.1
102	0.0158	2.75	0.40	--	0.04	--
106	0.385	24.8	4.11	2.12	0.2	0.08
118	0.0609	11.6	1.32	--	0.1	--
119	0.0206	18.1	2.59	1.36	0.1	0.06
120	0.0795	69.7	11.6	--	0.6	0.2
124	0.285	104	20.5	8.0	0.8	0.47
142	0.00259	0.316	--	--	--	--
143	0.00740	62.3	9.7	5.1	0.3	0.25
147	0.0128	72.6	12.7	6.40	0.46	0.3
148	1.790	891	170	54.1	9.6	4.1
149	0.756	255	54	16.8	2.17	0.97
150	0.035	188	37	8.6	1.54	0.71
192	0.115	73.7	12.2	--	0.99	0.21
194	0.140	82.7	14.0	--	0.91	0.31
195	0.725	699	162	51.0	7.36	2.94
196	0.00413	0.18	--	--	--	--
198	0.801	591	90.1	--	7.32	3.1
221	1.790	517	109	34.8	4.83	2.50
222	0.0664	266	50.5	19.3	2.27	1.17
224	0.0476	22.5	3.59	--	0.29	--
268	0.832	184	0.36	--	1.5	0.78
269	0.418	93.6	15.1	3.04	0.93	0.33
270	0.976	231	43.0	13.8	1.94	0.98
295	0.0276	0.79	--	--	--	--
314	0.505	68.0	11.7	--	0.96	--
316	0.0002	30.7	4.7	--	--	--
341	0.0264	51.3	7.89	--	0.55	--
342	0.085	14.1	1.89	--	0.11	0.05
343	0.0295	--	--	--	--	--
344	0.00186	0.036	--	--	--	--
Average =	0.316	145	21.9	7.0	1.44	0.61
Standard Error =	0.086	39.4	6.5	2.5	0.43	0.19

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