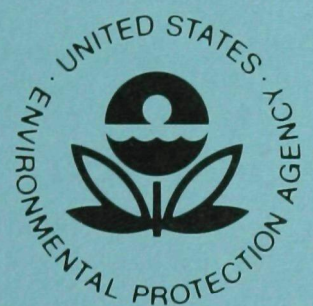
Technical Note
ORP/LV-77-2

RADIOLOGICAL SURVEY AT THE INACTIVE URANIUM MILL SITE NEAR RIVERTON, WYOMING

JUNE 1977



U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RADIATION PROGRAMS
LAS VEGAS FACILITY
LAS VEGAS, NEVADA 89114

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Richard L. Douglas

June 1977

OFFICE OF RADIATION PROGRAMS LAS VEGAS FACILITY
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PREFACE

Uranium mills are designed to extract uranium from ore which contains radioactive isotopes of the naturally-occurring uranium series decay chain. These isotopes, some of which are extremely long-lived, are discarded as mill wastes into large ponds and piles. Wind and water erosion have scattered the mill wastes over large areas of these sites' local environs, resulting in land contamination and increased population radiation exposure.

This survey was made at the request of the Wyoming Department of Health and Social Services to evaluate existing radiological conditions at the inactive uranium mill site at Riverton, Wyoming.

Donald W. Hendricks

Donald W. Hendricks
Director, Office of
Radiation Programs, LVF

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ACKNOWLEDGMENTS

The perseverance of Messrs. Jon Yeagley, Edd Johnson, Tom Fife, Joe Stano, and John Myers in making the gamma survey measurements are gratefully acknowledged. Mr. Myers also contributed to the study by contacting local residents and obtaining permission for water and radon progeny sampling, and by collecting the samples. His assistance in these areas is especially appreciated.

INTRODUCTION

In September, 1975 the State of Wyoming* (Johnson, 1975) requested, through the Nuclear Regulatory Commission (NRC), that the Environmental Protection Agency's (EPA) Office of Radiation Programs-Las Vegas Facility (ORP-LVF) conduct a survey to evaluate the radiological environmental status of the inactive uranium mill site near Riverton, Wyoming. Of particular interest was the extent of windblown tailings from the site. The State also requested that the Riverton site be included in the evaluation of inactive uranium mill sites which is being conducted jointly by EPA and the Energy Research and Development Administration (ERDA) The objectives of this evaluation program are described in the "Summary Report, Phase I Study of Inactive Uranium Mill Sites and Tailings Piles" (ERDA, 1974).

As a result of the State's request, a study was conducted at the Riverton site during the period September 30 to October 2, 1975. The organizations participating in the study included the State of Wyoming, EPA (ORP-LVF and Region VIII), NRC, Indian Health Service, and Solution Engineering, Inc. The individuals who conducted the survey are listed below.

HISTORY OF THE RIVERTON URANIUM MILL SITE

The Riverton mill site is about two and one-half miles southwest of the center of the town of Riverton, and is located on fee land within the Wind River Indian Reservation. Fremont Minerals, Inc. began operations at the site in 1958. The mill was later purchased by Susquehanna-Western, Inc., and milling

* Division of Health and Medical Services, Department of Health and Social Services

operations ended in June, 1963. The nominal capacity of the mill was 550 tons per day, and about 910,000 tons of tailings were generated. Based on the average grade of the ore processed, the tailings have a calculated average radium-226 concentration of about 660 pCi/gram, and the total radium content of the pile is estimated at about 500 Curies (PHS, 1970; radium data from USAEC Division of Occupational Safety).

The main mill building was partially dismantled in the early 1970's and most of the equipment was salvaged. Western Nuclear, Inc. is currently using some of the remaining facilities at the site to produce sulfuric acid which is used at operating uranium mills in the Gas Hills area. At the time of this survey, Solution Engineering, Inc. held an option to recover uranium from the tailings by means of a leaching process.

The original tailings pond and pile covered about 40 acres. In 1972, Susquehanna-Western stabilized the tailings pile. The pile was rearranged to cover about 80 acres,* fenced, and covered with a layer of clean material. The cover material was obtained from the immediate vicinity of the pile, and ranges from coarse gravel to the local topsoil. Clean fill was also placed on a portion of the ore storage yard northeast of the mill buildings. The covered pile was apparently seeded, but at the time of this survey, there was very little established vegetation on the pile. Bare tailings were visible at a few spots on the pile, and along most of the fence around the perimeter of the pile.

PREVIOUS SURVEYS

Previous radiological surveys were conducted at the Riverton site by the U.S. Public Health Service (PHS) in June 1970 (PHS, 1970), and by the U.S. Atomic Energy Commission (AEC) in March 1973 (AEC, 1973).

* The nominal area inside the fence (See Figure 1). The actual pile covers 72 acres, according to the Phase II Engineering Assessment made by Ford, Bacon & Davis Utah Inc.

During the AEC survey on March 13, 1973, water samples were collected at three locations and soil samples were collected at 20 locations. The water samples were analyzed for natural uranium, thorium-230, and radium-226. Radium and thorium concentrations were below the detection limit (0.09 and 0.4 pCi/1, respectively) in all three samples. Uranium concentrations in water were 3.7 pCi/1 at a residence 600 feet south of the tailings pile, 10 pCi/1 in Riverton, and less than the detection limit of 1.8 pCi/1 at a residence 3200 feet northeast of the pile.

Nineteen of the 20 soil samples were analyzed for thorium-230 and radium-226, and 4 of the 19 were also analyzed for natural uranium. Three samples, collected on or immediately adjacent to the pile, had high levels of all three nuclides. Levels of radium and thorium were slightly elevated (up to about five times background levels) at locations 125 feet, 500 feet, and 1500 feet northeast of the pile at 30° azimuth; at a resi dence 1000 feet northeast of the pile at 60°; and at a residence 600 feet south of the pile.

Measurements of the direct (gamma) radiation level were made at each of the sampling locations. The type of instrument used and its sensitivity were not reported. The only report of these results was the statement that "These measurements did not reveal the presence of radioactivity deposits other than those also shown through soil sampling."

The PHS survey was conducted on June 29, 1970. In addition to the environmental radiological aspects of this survey, other objectives were to answer questions which had been raised regarding selenium toxicity to livestock in adjacent pastures, and regarding possible contamination of salvage materials which were being removed from the site.

External gamma exposure rate measurements were taken on and around the pile and mill using an Eberline E-500B geiger survey meter. Elevated gamma levels (greater than a background rate of 0.03-0.04 mR/hr) were not found further than about 60 feet from the pile.

Lumber which had been removed from the site was located and monitored for alpha contamination with an Eberline PAC-1SA. Isolated spots of surface contamination were found, with the maximum reading being 6800 dpm/100 cm^2 (instrument background was 500 dpm/100 cm^2). The report concluded that the surface contamination levels observed represented no health problems.

Other conclusions of the report were that the mill and tailings areas should be fenced to control access, and that the pile should be stabilized to prevent wind erosion of the tailings material.

STUDY PARTICIPANTS

The following individuals participated in the 1975 survey of the Riverton mill site:

Jon Yeagley, U.S. EPA, Region VIII
Richard Douglas, U.S. EPA, ORP-LVF
William Moore, U.S. EPA, ORP-LVF
Michael O'Connell, U.S. EPA, ORP-LVF
Edd Johnson, Wyoming Department of Health & Social Services
J. B. Baird, U.S. NRC, Region IV
Herman Paas, U.S. NRC, Region IV
John Myers, U.S. PHS, Indian Health Service
Tom Fife, Solution Engineering, Inc.
Joe Stano, Solution Engineering, Inc.

SURVEY METHODS

GAMMA SURVEY

The primary objective of this study was to determine the extent of windblown tailings around the site. The technique used to meet this objective was that developed for use in the gamma radiation surveys which were conducted at other inactive uranium mill sites as part of the joint ERDA/EPA evaluation of these sites. Basically, the survey technique consists of taking ground-level gamma measurements with a modified Baird-Atomic NE-148A scintillometer.

The theory and methods used in this survey technique are described by Douglas and Hans (1975), and summarized by the following excerpt from that report:

> "The NE-148A contains a one inch by one and one-half inch NaI crystal detector calibrated with radium-226. The output is in microroentgens per hour (μR/h), with a range of 0 to 3,000 μR/h. The time constant of the scintillometers was increased to ten seconds in order to lessen the rapid meter fluctua tion, thereby reducing the need for subjec- tive averaging of readings by the operator. In addition, the instruments used in this study have a sliding lead shield attached which can be interposed between the detector and the ground. At a given location, two readings were taken with the scintillometer placed on the ground. One reading was taken

with the shield between the detector and the ground ("closed" reading) and one with the shield removed ("open" reading). The effect of the shield on a "closed" reading is to significantly shield the detector from any gamma photons originating from the ground beneath the scintillometer, while having essentially no effect on gamma shine from a distant source, such as the pile. Therefore, if tailings are present at the location of the reading, there will be a significant difference between the "open" and "closed" readings. This differential gamma reading, referred to as "delta" (Δ), indicates the presence or absence of tailings at that particular location. It also provides an empirical estimate of the quantity of surface tailings present. While the units of the delta value are μR/h, it should be kept in mind that the delta value is not numerically equal to exposure rate."

Two-hundred-foot intervals were measured and flagged along the fence around the pile. At each measured point, perpendicula lines were extended out from the fence, and delta readings were taken at paced 200-foot intervals along these lines until background delta readings were obtained. This resulted in a 200-x 200-foot grid of readings around the pile. Background readings taken in the Riverton area established a background delta value of Δ4.

Several miscellaneous measurements of external radiation levels were made:

1. Three traverses were made on the pile to measure the approximate delta values and external gamma exposure rates on the covered pile. Spot measurements were made where visible patches of bare tailings were observed.

2. In the plowed field west of the pile, delta measurements were made at successive depth increments of five centimeters to determine the extent to which windblown tailings had been mixed into the soil profile.

3. Some special measurements were made to correlate gamma exposure rate, delta measurements, and radium concentration in the soil as a function of distance from the pile. These parameters were measured at 200-foot intervals along a line extending 1200 feet out from the fence along the north side of the pile. The starting point for this line was 1000 feet west of the northeast corner of the pile fence. The gamma exposure rate was measured with a Reuter-Stokes pressurized ionization chamber (PIC Model RSS-111) with a digital readout. Readings were taken at the ground surface and at a height of one meter. The gamma exposure rate at the ground surface and at one-meter height, as well as the delta measurement, was also measured with the scintillometer. Soil samples were collected at each measurement point using a metal scoop which collects a sample 100 centimeters square and five centimeters deep.

WATER SAMPLING

At the request of the Indian Health Service, water samples were collected from 12 private wells and at the St. Stephens School in the vicinity of the site. These wells averaged 250 feet in depth, with a maximum depth of 300 feet (personal communication, John T. Myers, IHS). A background well water sample was also collected in Riverton, and a surface water and a shallow

well water sample were collected on the site. All well samples were collected by filling a one-gallon container from the tap. The water samples were analyzed for dissolved radium-226 using the methods described by Johns (1975).

RADON PROGENY (WORKING LEVEL) SAMPLING

Air samples were collected at three locations to measure the indoor working level, using the Radon Progeny Integrating Sampling Unit (RPISU). This sampler collects radon progeny on a filter which is in close proximity to a thermoluminescent dosimeter (TLD) chip. A portion of the alpha particle energy released during decay of the radon progeny is deposited in the TLD. The TLD then is read out in the laboratory, and the reading related, by a calibration factor, to the working level in the air sampled.

A background sample was collected in Riverton, and other samples were collected at two houses (one unoccupied at the time) near the mill site. The houses were in the predominant downwind direction from the site, in an area which appeared to have the highest level of contamination by windblown tailings. An attempt was made to collect a 24-hour sample at each location in order to average the diurnal variations, but such a sample was obtained at only one of the locations.

MISCELLANEOUS SOIL AND TAILINGS SAMPLING

In addition to the soil samples discussed under the Gamma Survey (above), three additional soil samples were collected in the plowed field east of the pile. A grab sample of tailings material was collected from a bare spot on the pile. All these samples were analyzed for radium-226 using the methods described by Johns (1975).

RESULTS AND DISCUSSION

GAMMA SURVEY

The results of the gamma survey are shown in Figure 1. The delta value is shown at each measurement point. Iso-exposure rate lines were constructed on the basis of these delta values by the method of Douglas and Hans (1975). In keeping with current Environmental Protection Agency guidance (EPA, 1974) iso-lines corresponding to residual gamma exposure rates of 40 μR/hr, 10 μR/hr, and background were located. The significance of these lines is as follows (Douglas and Hans, 1975):

> "If scattered tailings and ore are removed from inside a given line (toward the pile), and if the pile is removed or covered to provide essentially complete gamma shielding, then the remaining tailings outside the line (away from the pile) would produce a net gamma exposure rate, three feet above ground, approximately equal to that of the line designation."

As can be seen in Figure 1, the most extensive area of contamination lies in a sector southeast of the pile. The maximum distance from the pile fence to the background line was about 2500 feet east of the southeast corner of the pile. The land in this sector is mostly undisturbed range land. The land immedi ately east and northeast of the pile is cultivated. This cultiva tion quite likely has reduced the level of surface contamination (as measured by the delta method) by mixing windblown tailings material into the soil. Therefore, more tailings have probably been deposited on the east and northeast sectors than the results of this survey indicate.

The results of the "depth test" conducted in the plowed field immediately east of the pile lend some credence to the above hypothesis. This test was made 50 feet east of a point along the fence which was 400 feet north of the southeast corner of the pile fence. A surface delta reading was taken, and successive five-centimeter depth increments of soil were removed, with a delta reading taken at each five-centimeter interval. The results of this test are shown in Table 1.

TABLE 1. DEPTH TEST IN PLOWED FIELD EAST OF TAILINGS PILE

Depth Increment (Centimeters)	Delta Reading (μR/hr)
Surface	9
5	10
10	9
15	7
20	5
25	5
30	4

Since the background delta reading was Δ4, the results of this test indicate that tailings have been mixed into the soil profile, at this particular location, to a depth of 20 to 30 centimeters. It should also be noted that slight increases in the delta readings occur along the survey lines, extending east from the pile, as they cross Highway 789 and the north-south road about 1500 feet east of the pile. This is undoubtedly due to increased surface contamination, relative to the plowed field, since these areas have not been cultivated.

In view of these results, the location of the 10 μR/hr line in the field east of the pile, and of both the 10 μR/hr and background lines in the field northeast of pile, should be considered only approximate, since they only represent current levels of surface contamination.

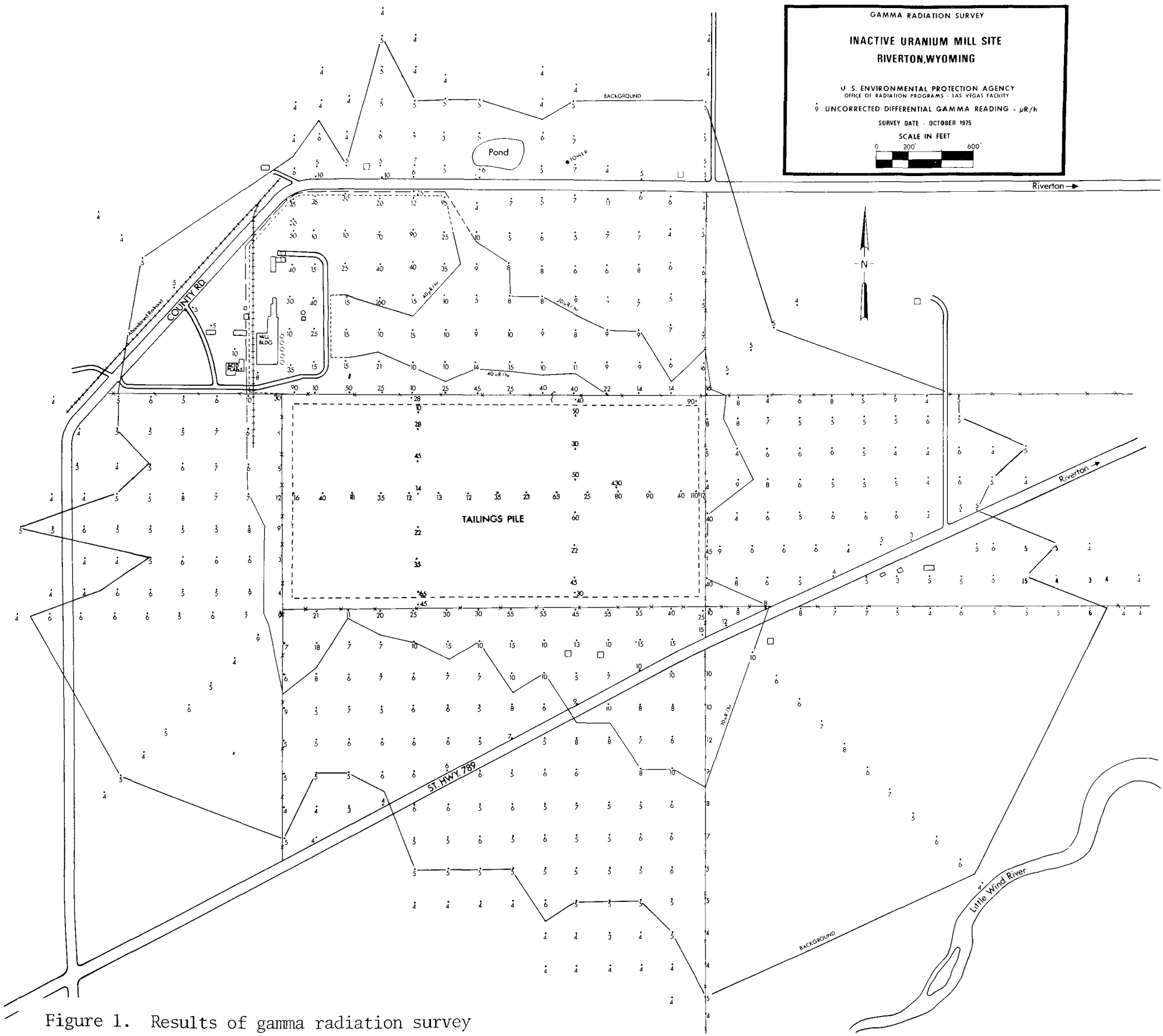

Figure 1. Results of gamma radiation survey

The 40 μR/hr line encompasses an area of about 30 acres, exclusive of the tailings pile. This includes a strip averaging about 200 feet in width along most of the north side of the pile, and former ore storage area northeast of the mill yard. The mill yard itself was arbitrarily included within the 40 μR/hr line, as indicated by the dashed line. The delta readings in the mill yard were too erratic to allow construction of the 40 μR/hr line, due to the spotty nature of contamination in the yard. However, it is apparent that the entire mill yard is sufficiently contaminated to warrant decontamination.

The 10 μR/hr line encompasses about 99 acres, exclusive of the tailings pile. As discussed above, the mill yard was included within this line. The dashed portion of this line along the west side of the mill yard and along the county road north of the mill indicate that the delta readings were not sufficiently uniform in these areas to allow the theoretical construction of the line. Therefore, the location of this portion of the line is somewhat subjective, and is based on adjacent readings and practical considerations for decontamination. Two houses south of the pile are within the 10 μR/hr line.

The background line encompasses about 460 acres, exclusive of the tailings pile. Except for the two cultivated fields discussed above, this is largely range or pasture land. About six houses are within the background line.

The results of the special measurements to correlate gamma exposure rate, delta readings, and radium-226 concentration in the soil are shown in Table 2. Figure 2 shows the one-meter gamma exposure rate (PIC), delta readings, and radium-226 concentrations as a function of distance from the pile. In a relatively undisturbed area, such as the one chosen for this test, these parameters are shown to correlate very well. An unexplained source of activity (probably ore spillage) was

TABLE 2. RADIOLOGICAL PARAMETERS AS A FUNCTION OF DISTANCE FROM THE TAILINGS PILE

Distance from Fence (Feet)[1]	Delta Reading (μR/hr)	Gamma Exposure Rate (μR/hr)				Radium-226 Concentration (pCi/gram ± two-sigma counting error)
		Surface		One-Meter Height		
		PIC[2]	Scint.[3]	PIC[2]	Scint.[3]	
6	30 13*	128	125	109	110	130 ± 2.1
100	20 12*	75	78	68	72	87 ± 1.7
200	12 7*	51	54	50	55	32 ± 1.0
400	9 5*	34	38	33	36	28 ± 0.97
600	6 5*	26	28	26	29	12 ± 0.62
800	6 5*	24	28	23	30	8.2 ± 0.53
1000	8 9* 5**	21	28	22	28	17 ± 0.75 (0-5 cm) 8.3 ± 0.53 (5-10 cm)
1200	8 5*	21	27	21	26	8.6 ± 0.54

[1] The toe of the stabilized pile is about 80 feet inside the fence. Therefore, 80 feet should be added to these distances to obtain the distance from the edge of the pile.

[2] Pressurized Ionization Chamber

[3] NE-148A Scintillometer

* Delta reading in 5-cm deep trench

** Delta reading in 10-cm deep trench

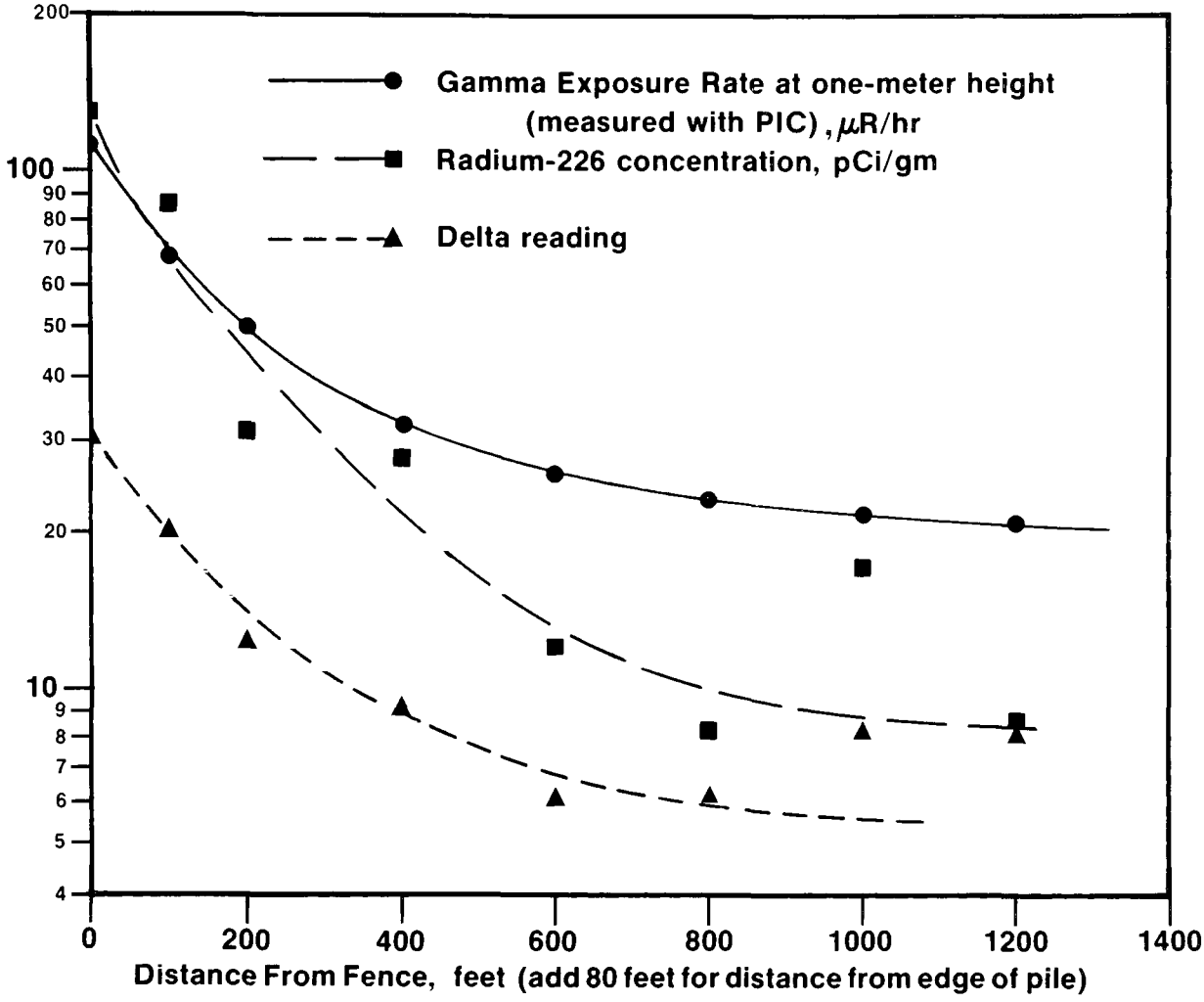

Figure 2. Radiological parameters as a function of distance from the tailings pile

detected by both the delta and the radium-in-soil measurements about 1000 feet from the pile. This contaminated area was not reflected, however, by the gamma exposure rate measurements. This may be because the small increase was less than the sensi tivity of the PIC, or because the one-meter gamma measurements "average" over a larger area than do the surface measurements. Whatever the reason, the delta method is shown to be a sensitive indicator of soil contamination.

WATER SAMPLING

The water sampling locations and the dissolved radium-226 concentrations are shown in Figure 3 and Table 3, respectively. Sampling locations #1 through #13 were residential wells in the vicinity of the pile, while #14 was in Riverton and is presumed to be a background sample free of any possible influence from the mill site. The samples were collected primarily to determine any potential radiation exposure to people drinking water from these wells. Consequently, no specific hydrologic information regarding the site was obtained. However, some inferences may be drawn regarding the pile as a possible source of ground-water contamination.

A cumulative log probability plot of the 14 data points (including the background) produced a straight line. The Kolmogorov-Smirnov goodness-of-fit test indicated that the observed distribution cannot be rejected as not being log-normal at the 99 percent confidence level, thus inferring that all the samples are probably from the same population.

From a hydrologic viewpoint, an eastward ground-water flow direction is assumed likely, regardless of whether the Wind River or the Little Wind River are line sources or line sinks relative to the water table. For this reason, samples #1 through #9 are located in areas likely to be hydraulically downgradient from the tailings pile, while samples #10 through #13 are located upgradient from the pile and are least likely to be affected by it. A t-test indicated no significant difference, at the 95 percent confidence level, between these two groups of samples. Consequently, there is no reason to believe that ground-water contamination, as indicated by radium-226 concentrations, is present in close proximity to the pile or in downgradient areas to the east and northeast.

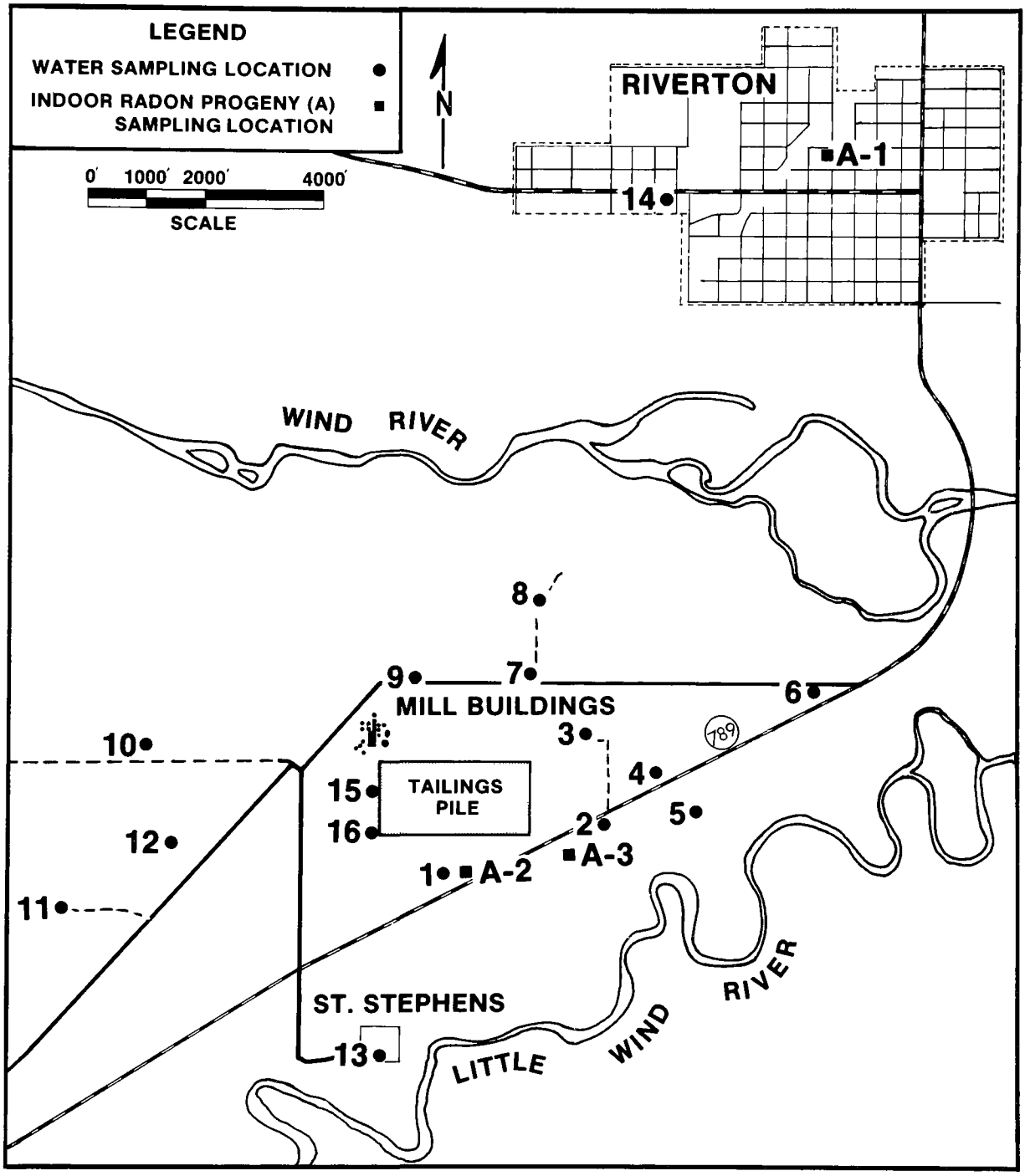

Figure 3. Location of water and radon progeny (working level) samples

Another basis for evaluating the water sample results is by comparing them to current standards. The Environmental Protection Agency Drinking Water Standards (EPA, 1976) allow a maximum combined level of radium-226 and radium-228 of 5 pCi/l. Although radium-228 was not measured in these samples, it has been reported (EPA, 1976) that it is almost always lower than the radium-226 concentration in the same water sample. Since the maximum radium-226 concentration in these samples is less than 20 percent of the 5 pCi/l standard, it is unlikely that total radium concentrations in water approaching the EPA standard are present in the vicinity of the mill site.

RADON PROGENY (WORKING LEVEL) SAMPLING

Indoor working level (WL) sampling locations and results are shown in Figure 3 and Table 4, respectively.

The guidelines set forth by the Surgeon General of the U.S. Public Health Service (PHS, 1970a) serve as a basis for evaluating these results. This guidance, which was established for continuous occupancy situations, states that no remedial action is indicated at levels below 0.01 WL, that remedial action may be suggested between 0.01 and 0.05 WL, and that remedial action is indicated above 0.05 WL.

The standard sampling procedure for the RPISU calls for at least a 24-hour sampling period in order to average the diurnal variations in radon and progeny concentrations. However, due to operational problems with the samplers, only one such sample was obtained. Furthermore, a comprehensive sampling program to properly evaluate indoor working levels requires several samples collected over a period of at least one year in order to average the annual variations. Consequently, these one-time, short-duration samples were, at best, a screening test to indicate potential problem areas.

TABLE 3. DISSOLVED RADIUM-226 CONCENTRATIONS IN WATER

Location*	Radium-226 Concentration (pCi/l ± two-sigma counting error)
1	0.26 ± 0.083
2	0.47 ± 0.10
3	0.078 ± 0.047
4	0.96 ± 0.15
5	0.44 ± 0.10
6	0.47 ± 0.11
7	0.15 ± 0.093
8	0.43 ± 0.15
9	0.27 ± 0.11
10	0.57 ± 0.17
11	0.16 ± 0.069
12	0.33 ± 0.093
13	0.19 ± 0.068
14 (Background)	0.22 ± 0.079
Ditch at west end of pile	0.32 ± 0.088
Reinjection well at SE corner of pile	0.41 ± 0.098

* Numbered locations correspond to numbers shown in Figure 3.

TABLE 4. INDOOR RADON PROGENY(WORKING LEVEL) RESULTS

Location*	Sampling Time (Hours)	Working Level
A-1 Background in Riverton	14.8	0.0009
A-2 Residence (unoccupied at time of sampling)	24.7	0.0029
A-3 Residence	0.9	0.0055

* Numbers correspond to locations shown in Figure 3.

With these qualifications in mind, it does not appear that significantly elevated indoor working levels exist in the vicinity of the mill site.

MISCELLANEOUS SOIL AND TAILINGS SAMPLING

The analytical results for these samples are shown in Table 5.

TABLE 5. RADIUM-226 CONCENTRATIONS IN TAILINGS AND MISCELLANEOUS SOIL SAMPLES

Sample Type and Location	Radium-226 Concentration (pCi/gram ± two-sigma counting error)
Exposed tailings on pile	660 ± 4.7
Soil from field east of pile:	
At fence	77 ± 1.6
200 feet east of fence	3.3 ± 0.34
400 feet east of fence	3.2 ± 0.33

Unfortunately, a background soil sample was not collected during this survey to serve as a basis for comparison. However, the soil concentrations of about 3 pCi/gram appear to be elevated relative to "normal" radium levels in soil. This is to be expected in view of the elevated delta readings obtained in this area. The radium concentration measured in the single tailings sample agrees very well with the values estimated by the USAEC for the Riverton pile (PHS, 1970).

SUMMARY AND CONCLUSIONS

A radiological survey was made of the inactive uranium mill site near Riverton, Wyoming during the period September 30-October 2, 1975. The primary purpose of the survey was to delineate areas which are contaminated by windblown material from the tailings pile. Secondary purposes were to collect water samples from local wells, and to collect indoor radon progeny (working level) samples in structures near the site, in order to identify any major radiation exposures which may be occurring through these exposure pathways.

The contaminated areas were delineated by making a series of differential gamma exposure rate measurements at the ground surface. A total of about 460 acres, exclusive of the tailings pile, was found to be contaminated above background levels. An area of 30 acres would have to be decontaminated to reduce the maximum residual exposure rate to 40 μR/hr, and 99 acres would have to be decontaminated to reduce the maximum residual exposure rate to 10 μR/hr.

On the basis of the limited water and working level sampling conducted during this survey, none of the sample results exceeded the guidance established by the EPA under the Safe Drinking Water Act or the Surgeon General's guidelines for indoor radon progeny levels.

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16. ABSTRACT

A radiological survey was made of the inactive uranium mill site near Riverton, Wyoming during the period September 30-October 2, 1975. The primary purpose of the survey was to delineate areas which are contaminated by windblown material from the tailings pile. Secondary purposes were to collect water samples from local wells, and to collect indoor radon progeny (working level) samples in structures near the site, in order to identify any major radiation exposures which may be occurring through these exposure pathways.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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