UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
HYDRO RESOURCES, INC.	)	Docket No. 40-8968-ML
2929 Coors Road, Suite 101	)	ASLBP No. 95-706-01-ML
Albuquerque, NM 87120	)	January 11, 1999

CERTIFICATE OF SERVICE

I hereby certify that on January 11, 1999, copies of Eastern Navajo Diné Against Uranium Mining's and Southwest Information and Research Center's Brief Regarding Radioactive Air Emissions at the Crownpoint Project, Testimony of Bernd Franke, and report entitled "Crownpoint Uranium Solution Mining Project: Review of Outdoor Radon Levels and External Gamma Radiation," along with all attachments and exhibits thereto, were served by Federal Express (denoted by asterisk) or first class mail on the following:

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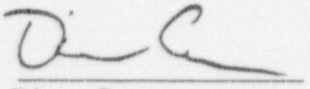

Diane Curran

ATTACHMENT A

UNITED STATES OF AMERICA
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	)	
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Albuquerque, NM 87120)	)	
	)	

TESTIMONY OF BERND FRANKE

1. My name is Bernd Franke. I am the president of Franke & Associates, an environmental consulting firm located in Takoma Park, Maryland. I am also a member of the board of directors, and the Director of Environmental Programs, of the IFEU-Institut für Energie- und Umweltforschung (Institute for Energy and Environmental Research) in Heidelberg, Germany, a 20-year old multidisciplinary consulting firm that handles a broad range of environmental projects. From 1984 to 1998, I was the executive director of the Institute for Energy and Environmental Research (IEER), a nonprofit organization based in Takoma Park, Maryland, dedicated to providing members of the public and policy makers with sound scientific advice on a variety of environmental and health issues, including nuclear facility safety and waste cleanup, nuclear disarmament, and global warming.

2. I have the German equivalent of a Masters degree in biology and geography. I have worked for 20 years in the field of radiation related risk and dose assessments, as well as on waste management and air toxicology problems. A copy of my vita and a publication list is attached to this testimony as Exhibit 1.

3. In my positions with IFEU, IEER, and Franke & Associates, I have performed many environmental studies in Europe, the United States, and elsewhere around the world. While working at IFEU in Germany, I was responsible for the preparation of many environmental projects, including the design and supervision of environmental monitoring programs, the modeling of atmospheric dispersion of radionuclides and other pollutants, and the assessment of health risks. These studies were prepared for a large variety of clients including Federal, State, and Local Governments, international organizations such as the European Union, as well industrial clients and ~~as~~ private citizens. In 1980 and 1981, I was the project director for the risk assessment of the proposed fast breeder reactor in Kalkar, Germany, a study commissioned by the German Federal Department of Research and Technology. In addition to overseeing the entire project, I was in charge of modeling the atmospheric transport of radionuclides and the subsequent radiation exposure to members of the public. In 1980, I was a court-appointed expert in a ~~the~~ case before the Court of Lüneburg regarding the licensing of the Brokdorf nuclear power plant in Northern Germany, and testified on the expected exposures of members of the public from releases of radioactive materials. From 1984 to 1986, I was the project director of an in-depth evaluation of the environmental monitoring system of the Three Mile Island Nuclear Facility under contract with the TMI Public Health Fund, Philadelphia, PA. In 1986, I was the project director for the assessment of the radiation exposures of residents in the German State of Hamburg caused by the Chernobyl accident. The State Health Department commissioned this study.

4. In addition, I was the project director for about ten environmental impact assessments which were prepared on behalf of various clients seeking licenses for releases of airborne

pollutants and the disposal of solid waste (*e.g.*,the City of Cologne, Germany for the licensing of a solid waste incinerator (1990); the Sanitation Department of the City of Munich, Germany for the license for a sewage sludge incinerator (1992); and the EAM Umwelt GmbH, an electric utility company in Kassel, Germany, for the licensing of a solid waste gasification facility (1996).

5. In my capacity as Executive Director of IEER, I was responsible for many research projects regarding the environmental impacts of a variety US nuclear installations. In 1989, on behalf of neighbors of a uranium-processing factory in Fernald, Ohio, I conducted research and testified about radiation exposures of members of the public due to releases of radioactive materials at the facility. The case, *Kenneth Crawford et al. v. National Lead of Ohio, et al.* was settled for an award of $78 million. In 1994, on behalf of former workers at the Fernald plant, I provided deposition court testimony on occupational radiation exposures at the facility. That case, *David Day, et al. v. National Lead of Ohio*, was also settled for an award of $20 million. In 1993, I provided court testimony regarding the exposures of members of the public from releases of radioactive materials at the Cotter Uranium Mill in Canyon City, Colorado, (*Lynn E.and Deyon Boughton et al., v. Cotter Corporation, et al.*). The case was resolved in a confidential settlement. In 1995, I gave testimony regarding the impacts of radium-226 and radon-222 resulting from the exploration on behalf of neighbors of an oil exploration project by Ashland Oil in Kentucky. The case, *Bartrum et al. v. Ashland Oil Corporation et al.*, was settled out of court. Most recently, in 1998, I conducted a dose reconstruction for residents in the vicinity of the Apollo Uranium Facility in Apollo Pennsylvania. In August of 1998, testified in this matter in Federal Court in Pittsburgh, in the case of *Hall et al. v. Babcock & Wilcox Company et al.* The jury awarded $36.7 million to the first eight plaintiffs; the case is still pending.

6. From 1992 to 1994, I was a member of the international Scientific Management Team of the Rongelap Resettlement Project, a project funded by the U.S. Congress for former residents of Rongelap Atoll in the Marshall Islands that was affected by atmospheric U.S. nuclear weapons tests. The objective of the studies was to determine whether resettlement of the atoll was safe, *i.e.*, whether cleanup of radioactive fallout had achieved compliance with preset dose limits. I conducted measurements of plutonium in bone tissues of deceased former residents and was actively involved in the design of the study and the final dose assessment.

7. The purpose of this testimony is to describe my professional opinion regarding the adequacy of Hydro Resources Inc.'s license and license application to maintain airborne radon emissions within regulatory standards, and to address the environmental impacts of HRI's airborne radon emissions.

8. In preparing the testimony, I reviewed relevant portions of dozens of documents, including the Draft and Final Environmental Impact Statements, the Environmental Reports prepared by Hydro Resources, Inc., correspondence between HRI and the NRC Staff regarding the emissions and environmental impacts of the proposed Crownpoint Project, and the results of HRI's calculations of atmospheric releases using the MILDOS dispersion model. The documents that I rely on for my testimony are referenced in my attached report.

9. I am familiar with the regulations of the NRC and the U.S. Environmental Protection Agency ("EPA") regarding control of radioactive air emissions. I am also familiar with computer codes used by the government and the nuclear industry to model radiation doses, including the codes MILDOS, CAP88 and RESRAD.

6. The attached Report, entitled -- "Crownpoint Uranium Solution Mining Project:

Review of Outdoor Radon Levels and External Gamma Radiation" describes the review that I conducted and the conclusions that I reached. A copy of the Report is attached to my testimony as Exhibit 2. I hereby adopt and incorporate the Report by reference into my testimony.

7. To summarize my conclusions regarding HRI's airborne releases, I have found that on the basis of the available data, the proposed HRI project is not in compliance with the 10 CFR Part 20 regulations regarding exposures to gamma radiation and radon and its progeny. In addition, the Final Environmental Impact Statement underestimates and fails to adequately address the significant environmental impacts of airborne radiological releases at the Crownpoint Project. Therefore, in my view, it is deficient.

I declare and affirm, under penalty of perjury, that the foregoing facts are true and correct to the best of my knowledge, and that the opinions expressed herein are based on my best professional judgment.

Bernd Franke

DATED: January 6, 1999

EXHIBIT 1
TO FRANKE TESTIMONY

Bernd Franke **Curriculum Vitae**

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EDUCATION

1972-1975	University of Marburg: Biology and Geography
1975-1978	University of Heidelberg: Biology and Geography
1978	German equivalent of Master's Degree in Biology with a thesis on plant nutrition (University of Heidelberg)
1978	German equivalent of Master's Degree in Geography with a specialty in soil science (University of Heidelberg)

EMPLOYMENT HISTORY

1978-1979	radioecological research on the environmental effects of the proposed reprocessing plant at Gorleben for the Department of Social Affairs (air and water pathway), State of Lower Saxony, Federal Republic of Germany
1979-1981	member of the senior research staff of IFEU-Institut für Energie- und Umweltforschung Heidelberg *(Institute for Energy and Environmental Research)*: participation in various projects on radioecology and nuclear accident consequences and related topics (see publication list)
1981-1983	project director at the Institute for the "Risk Oriented Study of the Fast Breeder Reactor SNR-300 at Kalkar - Environmental Impacts of Accidents", for the Department of Research and Technology, Bonn, Federal Republic of Germany

1984-1998	Executive Director of the U.S. office of the Institute for Energy and Environmental Research (IEER); responsible for various projects on environmental monitoring of air and water pollution, landfill safety and ecobalances
1991-today	Director of Environmental Programs at IFEU-Institut für Eneregie- und Umweltforschung Heidelberg, member of the board of directors
1992-1996	Member of the Scientific Management Team of the Rongelap Resettlement Project
1998-today	President of Franke & Associates

PROFESSIONAL MEMBERSHIPS

Health Physics Society, U.S.A.
Federation of Radiation Protection, Federal Republic of Germany
Society for Ecology, Federal Republic of Germany

PERSONAL INFORMATION

Birth:	June 7, 1953
Citizenship:	Federal Republic of Germany Resident Alien Status in the United States
Civil status:	married, one child

PUBLICATIONS

1. Bruland, W.; Erhard, T.; Franke, B.; Grupp, H.; v.d. Lieth, C.W.; Matthis, P.; Moroni, W.; Ratka, R.; v.d. Sand, H.; Sonnhof, U.; Steinhilber-Schwab, B.; Teufel, D.; Ulfert, G.; Weber, T.; "Radioökologisches Gutachten zum Kernkraftwerk Wyhl", Tutorium Umweltschutz an der Universität Heidelberg, Mai 1978, 2. Aufl. Juli 1978 *(Radioecological Assessment of the Wyhl Nuclear Power Plant", Department of Environmental Protection of the University of Heidelberg, Heidelberg, May 197[illegible] vised July 1979; NRC Translation 520 (available from Nuclear Regulatory Co[illegible]sion, Washington, D.C.)*
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4. Franke, B.; Höpfner, U.; "Zur Abschätzung des Transfers von Radionukliden aus dem Futter in tierische Nahrungsmittel (Fleisch)", Modellstudie Radioökologie Biblis Bd. 9; im Auftrag des Hessischen Ministers für Wirtschaft und Technik durch das IFEU-Institut für Energie- und Umweltforschung Heidelberg e.V.; *(Transfer of Radionuclides from Fodder into Animal Food Products (Meat); Model Study Radioecology Biblis for the Hessian Minister of Research and Technology)*, Wiesbaden, 1980
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EXHIBIT 2
TO FRANKE TESTIMONY

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Crownpoint Uranium Solution Mining Project: Review of Outdoor Radon Levels and External Gamma Radiation

prepared for the

Eastern Navajo Diné Against Uranium Mining Crownpoint, NM,
and
Southwest Research and Information Center, Albuquerque, NM

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Table of Contents

1 Introduction

This report contains a review of the impacts of the proposed Crownpoint Uranium Project with respect to radiation exposures and focuses on the following aspects:

- existing levels of radon and external gamma radiation at Crownpoint and Church Rock,
- predictions of radon emissions from solution mining operations,
- predicted incremental radon concentrations in the environment, and
- compliance of environmental levels of radon and external gamma radiation with 10 CFR Part 20 standards.

In addition to radon and its daughters, other radionuclides (such as uranium, thorium and radium) are emitted during various time periods of the mining operation and subsequent restoration of the site. Their impact is not evaluated in this report and would have to be added for a comprehensive assessment of radiation doses.

2 Regulatory Requirements

Airborne releases of radon and its daughters and the subsequent radiation exposures to members of the public from HRI operations are governed by the Nuclear Regulatory Commission (NRC) under 10 CFR Part 20.

10 CFR Part 20 states: "It is the purpose of the regulations in this part to control the receipt, possession, use, transfer, and disposal of licensed material by any licensee in such a manner that the total dose to an individual (including exposures to licensed and unlicensed radioactive material and from radiation sources other than background radiation) does not exceed the standards for protection against radiation prescribed in the regulations in this part." [10 CFR § 20.1001 (b)]

10 CFR § 20.1301 (Radiation Dose Limits for Individual Members of the Public) further requires that:

> (1) Each licensee shall conduct operations so that [t]he total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 millisievert) in a year, exclusive of the dose contributions from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released in accordance with § 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003, and
>
> (2) The dose in any unrestricted area from external sources, exclusive of the dose contributions from patients administered radioactive material and released in accordance with § 35.75, does not exceed 0.002 rem (0.02 millisievert) in any one hour.

In the context of compliance assessment, it is important to review the precise definition of "background" in § 20.1003:

> "*Background radiation* means radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee. "Background radiation" does not include radiation from source[1], byproduct[1], or special nuclear materials regulated by the Commission."

Therefore, to the extent that radon-222 is a decay product of radium-226 as a constituent of source material (ores with a uranium and/or thorium content of greater than 0.05%) and/or of byproduct material (such as mill tailings), it is not considered to constitute background radiation. Accordingly, existing radon levels generated by previous uranium mining activities in the area of a proposed licensed activity cannot be excluded as background, and must be considered in evaluating compliance with 10 CFR Part 20.

10 CFR § 20.1302 provides that compliance with dose limits for individual members of the public can be established:

- by demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit; or
- by demonstrating that the annual average concentrations of radioactive material released in gaseous and liquid effluents to the boundary of the unrestricted area do not exceed the values specified in table 2 of appendix B to Part 20; and that if an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year.

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[1] The terms "source material" and "byproduct material", which are relevant for purposes of regulating in situ leach mining and milling, are defined in 10 CFR § 20.1002 as follows:

Source material means— (1) Uranium or thorium, or any combination of uranium and thorium in any physical or chemical form; or (2) Ores which contain, by weight, one-twentieth of one percent (0.05 percent), or more, or uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Byproduct material means— (1) Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear material; and (2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute "byproduct material" within this definition.

The maximum levels of radon-222 permitted by 10 CFR 20 Part 20 are listed in appendix B, table 2 are as follows:

Radionuclide	Class	Air (μCi/ml)	Air (pCi/l)
Radon-222	With daughters removed	1E--8	10
	With daughters present	1E--10	0.1

Regarding radiation exposures , the licensee has two options to show compliance with 10 CFR Part 20:

1. by demonstrating that the total effective dose above background to any individual in the unrestricted area does not exceed 100 millirem per year; or
2. by demonstrating that the concentrations of radon-222 (with daughters present) in the effluent to the boundary of the unrestricted does not exceed 0.1 pCi/l above background; ; and that if an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem in an hour and 0.05 rem in a year.

It should be noted that the air concentration values in appendix B, table 2 are equivalent to air concentrations that, if inhaled continuously over the course of a year, would produce a total effective dose equivalent (TEDE) of 50 millirem. The rationale for the 50 millirem per year limit from inhalation of airborne radioactivity is that it allows for an additional maximum dose of 50 millirem per year from external radiation, such that the total dose from both pathways would be a maximum of 100 millirem TEDE per year.

The external gamma dose from radon-222 and its daughters is negligible. Thus, if only radon (and no sources of gamma radiation) were to be considered, an annual average concentration of 0.2 pCi/l of radon-222 (with daughters present) is equivalent to 100 millirem TEDE per year. However, as discussed below, residual gamma radiation from previous mining activities is also a relevant consideration in evaluating radiation doses for the Church Rock site.

3 Existing Exposure Levels at the Church Rock Site

In order to evaluate HRI's compliance with Part 20 radiation limits and the environmental impact of airborne radioactive material at Church Rock, I performed two analytical steps. First, I analyzed existing levels of radon and external gamma radiation at the site, and attempted to distinguish background levels from non-background contributions. Second, I evaluated the likely dose contribution of HRI's operation itself, and its relationship to the dose limits.

3.1 Radon

Typical outdoor background levels of radon[2] in the continental US range from 0.1 to 0.2 pCi/l[3]. Figure 1 illustrates the typical seasonal and diurnal variation of the activity. The multi-year seasonal variation indicates difference of up to a factor of 3 over a four-week period.

No background radon data are given in the Final Environmental Impact Statement (FEIS) for the Crownpoint Uranium Project.[4] However, background radiological characteristics of the Unit 1-Crownpoint and Church Rock areas were summarized in the Draft Environmental Impact Statement[5] (DEIS) (see, Table 3.2 and 3-19 through 3-22), based on monitoring data reported in different parts of HRI's license application.

For Crownpoint, the DEIS (at 3-19) reports average airborne radon concentrations at two stations of 0.22 pCi/l and 0.26 pCi/l, with an average concentration for all locations of 0.35 pCi/l and a range of 0.20 pCi/l to 0.60 pCi/l. The average concentrations for the two stations were derived from seventeen measurements taken over a 19-month period between February 1981 and September 1982 at two unspecified locations in Crownpoint.[6] According to HRI's application, charcoal canisters were used to collect these measurements.[7] The data themselves are summarized in Table 1 of this report and are shown in Exhibit A, which is a copy of Table 2.9-2 from HRI's Crownpoint Supplementary Environmental Report (April 1989), at 52. As shown in Table 1 and

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[2] In nature, radon is composed of radon-222 (half-life 3.8 days) and radon-220 (with a half-life of 56 seconds). The major contributor to dose is radon-222. Environmental measurements do not distinguish between the two isotopes.

[3] National Commission on Radiological Protection (NCRP). Exposure of the Population in the United States and Canada from Natural Background Radiation. NRCP Report No. 94. Bethesda, MD 1987

[4] NUREG-1580, Final Environmental Impact Statement to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico, February 1997.

[5] NUREG-1580, Draft Environmental Impact Statement to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico, October 1994.

[6] Hydro Resources, Inc., Supplementary Environmental Report, New Mexico Uranium Production Operations (April 20, 1989) (ACN 9509070065); transmitted by letter from Mark S. Pelizza, HRI, to Tom Olson, NRC (May 8, 1989) (ACN 8907100159) (hereinafter refered to as "Crownpoint Supplementary ER").

[7] Crownpoint Supplementary ER, at 50. There is no indication in the Supplementary ER who was responsible for taking these radon measurements or how HRI knows they were taken using charcoal canisters. Neither were the locations of the two monitoring stations described in narrative form or indicated on a map of the area.

indicated in Exhibit A, average radon concentrations for the "East" monitoring location ranged from 0.03 pCi/l to 0.57 pCi/l with an average of 0.22 pCi/l, and average concentrations for the "West" location ranged from 0.08 pCi/l to 0.87 pCi/l, with an average of 0.26 pCi/l.[8]

The overall average of 0.35 pCi/l and range of 0.20 pCi/ to 0.60 pCi/l reported in Table 3.2 of the DEIS apparently were based on air monitoring data for three locations taken over a two sampling periods of seven days each in April and May 1978 at the Mobil Oil Section 9 In Situ Pilot Facility, prior to commencement of operations there. These data are listed in Table 1 and shown in full in Exhibit B, which is a copy of Table 2.9-3 from HRI's Environmental Assessment for the proposed Unit 1 mine site (hereinafter, "Unit 1 EA").[9] No information was provided in the text of the Unit 1 EA that describes how these measurements were taken.

Background radon-222 data for the Crownpoint area also were obtained from a report authored by T. Buhl and published by the New Mexico Environmental Improvement Division in 1985 ("Buhl Study").[10] The Buhl Study gave ranges of average radon concentrations of 0.10 pCi/l to 0.13 pCi/l at one station in Crownpoint in 1978-79 and 0.15 pCi/l to 0.17 pCi/l at another Crownpoint location in 1979-80. These data are summarized in Table 1 of this report, and the relevant pages from the Buhl Study are attached hereto as Exhibit C. The Buhl Study used the Crownpoint monitoring locations to assess background ambient radon levels in an area not affected by underground uranium mining and conventional uranium milling and tailings disposal.

For Church Rock, the DEIS reports average airborne radon concentrations of 3.06, 1.19 and 2.22 pCi/l for each of three stations, with an overall average concentration of 2.16 pCi/l and a range of 0.10 pCi/l to 13.4 pCi/l. DEIS at 3-19. HRI collected these data from August 1987 through September 1988, using Track Etch devices[11] in which plastic films record alpha particle (i.e., alpha radiation) tracks, thus allowing for measurement of long-term average concentrations.[12] These data are shown in Exhibit D, which is a copy of Table 2.9-3 of HRI's Church Rock Revised Environmental Report (March 1993). As shown in Table 2.9-3, HRI took air samples for 14 different periods ranging in length from 18 to 42 days at each of the three Church Rock monitoring sites. The locations of

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[8]Although these data were were tabulated to reflect time periods between 20 and 64 days, the data taken at these stations reflect radon concentrations at equilibrium in the charcoal matrix a few days before the samples were analyzed. This is because the half-life of radon is 3.82 days.

[9] HRI, Inc. Environmental Assessment for HRI, Inc. Unit 1 Allotted Lease Program, Eastern Navajo District, New Mexico, submitted to U.S. Department of the Interior, Bureau of Indian Affairs (January 6, 1992) (ACN 9509080065), at 2-107.

[10] Buhl T. , Millard J., Baggett D. and Trevathan S., Radon and Radon Decay Product Concentrations in New Mexico's Uranium Mining and Milling District, Radiation Protection Bureau, New Mexico Health and Environmental Department, Final Report, March 1985

[11] According to NCRP Report 95, the lower limit of detection of these devices is 0.05 pCi/l to 0.2 pCi/l. See: National Commission on Radiological Protection (NCRP) Report No. 97, Measurement of Radon and Radon Daughters in Air. Bethesda, Maryland 1988, p.53

[12] HRI, Inc., Church Rock Project Revised Environmental Report (March 1993), at 161 (transmitted by letter from Mark S. Pelizza, HRI, to Raman R. Hall, NRC [March 16, 1993] [ACN 9304130415]) (hereinafter refered to as "Church Rock Revised ER").

those sites are shown on Figure 2 of this report and the average concentrations for each sampling period at each monitoring site are shown in Figures 3, 4 and 5.

Additional data on radon concentrations in the Church Rock area were obtained from a 1981 license renewal application document prepared for United Nuclear Corporation (UNC) and submitted to the New Mexico Environmental Improvement Division (NMEID).[13] Ambient radon concentrations at monitoring sites in and around the UNC uranium mill and tailings impoundment in Section 2 of T16N, R16W; at the UNC Old Church Rock Mine in Section 17 of T16N, R16W; and at "Springstead Trailer Park" site[14] located about 1.5 miles south of Section 17 are given in "Table D3", which was taken from the license renewal application and is attached this Report as Exhibit E. For the time period 10/3/80 to 7/16/81, the average track etch readings ranged from 2.4 to 3.8 pCi/l. Short-term radon concentrations were reported for selected days in 1977 and 1978 at sites near the mill and tailings facility and ranged from 0.03 pCi/l to 8.76 pCi/l.

Two features of the radon data reported by HRI for the Crownpoint and Church Rock sites indicate that while Crownpoint radon levels appear to be more or less at natural background levels, the radon levels at Church Rock are dominated by non-background sources.

First, the poor correlation between outdoor radon levels at the three Church Rock stations illustrates a significant variability between the monitored locations that is not explainable as normal background variation. For example, the radon levels at location 8R1 for September 1988 were reported to be 13 pCi/l, whereas the concentrations at the other locations during the same month did not exceed 2 pCi/l. It is notable in this regard that two of the measuring locations, 8R1 and 8R2, were in very close proximity to each other. Seasonal and diurnal variability should affect outdoor levels in close proximity in a similar way. In contrast, radon measurements at Crownpoint show much less variability. The lack of the expected correlation usually is a strong indicator of localized non-background sources, such as emissions from mill tailings or vents from uranium mines which are unlikely to impact all sampling locations simultaneously.

Second, the levels reported for Church Rock are consistently high; the magnitude of the concentrations is far in excess of what one would expect from natural background and thus constitutes a strong indicator of non-background activity. The results of all available measurements are summarized in Table 1. While one would expect natural background concentrations to be similar to those measured at Crownpoint (between 0.10 and 0.28 pCi/l), the levels at Church Rock are approximately one order of magnitude (i.e., roughly 10 times) higher than those in the Crownpoint area, and 10 to 20 times higher than the range of reported background radon concentrations nationally. It is highly likely that the

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[13] D'Appolonia Associates. State of New Mexico Environmental Improvement Division, Uranium Mill License Renewal Application – Environmental Report, License NM-UNC-ML, UNC Mining and Milling, Church Rock Operations, Division of United Nuclear Operations, Volume I, December 1981; relevant portions attached as Exhibit E

[14] The text of the license application stated that the Springstead site was considered a "background" monitoring location. The 10/80 to 7/81 average radon concentration at this location is reported to be 3.0 pCi/l. The Springstead site is located less than 1 mile south of the North Fork of the Puerco River and about two miles north of the Foust No. 3 uranium mine, and was thus impacted by mining-related radon. Thus, it is inappropriate to characterize this location as "background".

elevated levels of radon at Church Rock are due to significant contributions from non-background sources.

Prior uranium mining and milling activities are the most likely cause for the elevated concentrations of radon in the Church Rock area. As shown in Table 1, uranium mining in the Church Rock area dates to 1960-1962 at the "Old Church Rock Mine" in Section 17, to 1969 at the UNC Northeast Church Rock Mine in Section 35 (T17N, R16W), and to 1972 at the Kerr-McGee Church Rock I on the Navajo Reservation in the equivalent of Section 25 (T17N, R16W). Uranium milling and tailings disposal at the UNC mill complex began in Section 2 (T16N, R16W) in late-May 1977. Hence, all of the ambient radon concentrations reported by UNC in the 1981 license renewal application post-dated uranium mining activities and most of the uranium milling activities in the Church Rock district which took place in the 1960's and 1970's. The Springstead monitoring site, which UNC claimed as "background," is located within 2 miles of two uranium mines and within 1 mile of the North Fork of the Puerco River. The river itself is a possible source of radon from accumulation of uranium mine and mill effluent discharges between 1969 and 1986.

The existing non-background contributions at Church Rock clearly exceed the 10 CFR Part 20 compliance level of 100 mrem/yr TEDE which is equivalent to 0.2 pCi/l. Thus, the addition of another source of airborne radioactive materials would not be in compliance with 10 CFR Part 20.

3.2 External Gamma Radiation

In addition to a significant radon exposure above background, the Church Rock site is also characterized by increased gamma radiation levels representing pre-existing site contamination which "reflect the influences of previous mining and milling activities in the area".[15] Significant levels of gamma radiation appear to extend beyond the boundaries of HRI's mining project to unrestricted areas, such as the corridor of State Highway 566, and grazing lands on Section 9. Figure 6 shows an isopleth map of gamma readings taken in 1987. The background (upwind monitoring sites) is likely to be around 10 to 15 μR/hr. The isopleth at the Route 566 is approaching 50 μR/hr, so that the non-background dose rate is about 35 to 40 μR/hr, which is equivalent to ~300 to 350 mrem/yr for that location. That dose rate is far in excess of the 50 mrem/yr limit set in 10 CFR §20.1302(2)(ii).

In addition, it is noteworthy that no measurements were taken at the closest residence (CRR4, cf. FEIS p. 4-84). Given the magnitude of the readings in the vicinity, and the downwind location of the nearest residence (CRR4), it is possible that the dose rate at the closest residence exceeds 50 mrem/yr (equivalent to >5.7 μR/hr) above natural background. Thus, gamma dose rates at the Church Rock site for the cosest resident may also exceed the limit set in 10 CFR Part 20.

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[15] DEIS, at page 3-20

4 Calculation of Radon-222 Exposures from HRI Solution Mining Operations

The FEIS concludes that radiation doses from the Crownpoint project will be significantly below regulatory limits[16]. This conclusion is based on dose modeling with the MILDOS computer program using various assumptions about the source term of radioactive material, the atmospheric dispersion and the location of potential receptors[17]. The FEIS's conclusion regarding doses from airborne releases is unreliable because the underlying assumptions about the source term are based on an inappropriate interpretation of radon-222 measurements in the groundwater at the Crownpoint site. The NRC should have accounted for the significant variability of radon-222 measurements by performing an uncertainty analysis of the data, using appropriate models.

The FEIS estimates the annual radon-222 source terms for various locations at the Crownpoint project as follows:

Crownpoint and Unit 1 sites

Resin transfer/process circuit:	1.83 Ci/yr
Process circuit pressure vents:	2.96 Ci/yr

Church Rock[18]

Resin transfer/process circuit:	1.784 Ci/yr
Process circuit pressure vents:	2.96 Ci/yr

Section 12 land application area for both Crownpoint and Unit 1 sites

Restoration water at land application:	159 Ci/yr

These source terms are in turn based on NRC's assumption that the annual average radon-222 concentration in groundwater is 133,000 pCi/l[19]. It is apparent that the figure of 133,000 pCi/l was arrived at by averaging 25 measurements taken by HRI from production wells at Unit 1[20]. As shown in Table 3, however, the raw data on which the estimate of the average was based show a significant variability of measured concentrations, varying by a factor of 2,300 from 480 pCi/l to 1,100,000 pCi/l.

Given this significant variability of measured concentrations, it was inappropriate to take an arithmetic average without accounting for the uncertainty of the data. One may explain this issue with a simple example: Assume that the average income of two groups of 100 people is identical, say with $50,000/year. In the first group, ten people earn

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[16] FEIS at pages 4-78, 4-79, 4-83 and 4-85.

[17] FEIS at pages 4-74, 4-87

[18] Note that the source terms for Crownpoint and Church Rock are similar though not identical. While the source terms for process circuit pressure vents (2.96 Ci/yr) are identical, the estimate for the resin transfer/process circuit for Church Rock (1.784 Ci/yr) is about 3% smaller than for Crownpoint. No explanation is given for the discrepancy.

[19] FEIS at pages 4-74

[20] The NRC based this average on data that were submitted to the NRC by HRI in a letter dated June 18, 1996. If one attempts to reconstruct the average of 25 well samples submitted by HRI, the result is 150,000 pCi/l, rather than 133,000 pCi/l reported in the FEIS. The discrepancy could not be resolved. However, it is insignificant in comparison to the impact on dose calculations if the actual variability of the underlying data is considered.

$500,000/year, while the rest has no income at all; in the second group, all people have an income of $50,000/year. It is evident that the average income is a poor indicator for the economic situation of the two groups.

Based on the data provided by HRI regarding radon-222 measurements in groundwater, the hourly source term of radon-222 is expected to vary greatly over the hours of the year. This can be seen by the graphical representation of the data distribution (Figure 7). The cumulative frequency distribution of radon-222 concentration data can be approximated by a lognormal distribution ($\mu(\ln) = 9.63$, $\sigma(\ln) = 2.63$). In the uncertainty analysis, the distribution is used to approximate the variability in the hourly radon-222 source term. In addition to the variability of concentration data, there is the issue of uncertainties due to sampling and analytical methods; however, the latter uncertainty cannot be quantified in the absence of further information.

Given that the radon-222 concentrations in the groundwater of production wells varies over orders of magnitude, and that the release of airborne radon-222 is thus expected to vary considerably from hour to hour, it was inappropriate for the NRC staff to use a Gaussian dispersion model like MILDOS. MILDOS is only applicable for continuous releases. While the MILDOS manual does not address this issue directly, CAP-88PC, a comparable program which relies on the same dispersion model and is frequently used in compliance assessments, states in the manual section entitled "cautions" that "CAP88-PC cannot be used to model either short-term or high-level radionuclide intakes."[21]

The generalized equation for the estimation of air concentration (C) from a radionuclide release can be written as:

$$C = Q \times D$$

in which Q is the source term or the amount of radionuclide release and D is a term that reflects dispersion and dilution of the radioactive material in air. If the uncertainty distributions of Q and D are lognormal and independent, then the uncertainty distribution of the product C can be estimated using arithmetic procedures. In this case, the hourly source term and the hourly dispersion are reflected by lognormal distributions. Using statistical sampling from both distributions (Q *and* D), the uncertainty in the predicted annual average radon-222 concentration (C) can be calculated.[22] An Excal based spreadsheet program (Crystal Ball Version 4.0) was used for the calculations.

In order to properly model the uncertainty of the predicted radon-222 concentrations, the variability of the atmospheric dispersion coefficient also has to be addressed. This was done using the Gallup, NM weather data contained in the CAP88PC data package. The variability of the dispersion coefficient was determined for the predominant wind direction from WSW and a distance of 100 m, using appropriate coefficients in a spreadsheet model. The dispersion coefficients χ/Q were weighted with the relative frequency of wind speed and stability class for the wind direction from WSW and plotted in a

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[21] Barry Parks, U.S. Department of Energy, ER-8/GTN, 19901 Germantown Road, Germantown, Maryland 20874-1290, CAP88-PC Version 2.0 User's Guide, June 1997

[22] A detailed discussion of the methods and their implications can be found in: National Council on Radiation Protection and Measurements (NRCP). Commentary No. 14. A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination. Bethesda, MD USA, May 1996

cumulative frequency chart (see Figure 8). The distribution of the values was approximated with a lognormal fit to the data that was subsequently used in calculating the ambient air concentrations.

A distance of 100 m was selected as an estimate for the distance between the source of the emissions and the unrestricted area that would be marked by the fences around the buildings. A precise determination could not be made due to the lack of detail in the maps contained in the FEIS which do not indicating the precise location of the building fences. In the FEIS, on the other hand, the calculation of predicted air concentrations was limited to residences and boundary receptors (see FEIS, p.4-76 and 4-84). This is an inappropriate limitation because members of the public will have access to the mining sites and can get as close to the source as the building fence. The building fence marks the unrestricted areas for which compliance with 10 CFR Part 20 limits has to be established. This issue is especially important because of the variability of the radon-222 over time, which can cause significant exposures during a few hours of the year; a short exposure close to the source can yield a significant contribution to the annual average.

Three cases were analyzed:

- A base case assuming that the annual average Rn-222 concentration in groundwater is 133,000 pCi/l (as stated in FEIS),
- a lower case in which the annual average Rn-222 concentration in groundwater is assumed to be one fifth of the base case (27,000 pCi/l), and
- an upper case in which the annual average Rn-222 concentration in groundwater is assumed to be five times the base case (670,000 pCi/l).

The lower and upper case scenario was chosen because the average Rn-222 groundwater concentration of 133,000 pCi/l is based on measurements over two days for each well; the long-term averages are expected to vary from these short-term measurements[23]. A factor of five appears an appropriate estimate of this uncertainty. The result of the calculation is shown in Figure 9. For the upper case scenario, there is a greater than 50% probability that the annual average Rn-222 concentration exceeds the limit of 10 CFR Part 20 for radon-222 in air of unrestricted areas (0.1 pCi/l with daughters present). For the base case, the probability is about 1%; for the lower case, it is unlikely that the limit will be exceeded.

Thus, the FEIS failed to address the considerable uncertainty of the annual average source term of radon-222 and underestimated the potential impact of HRI operations. When the uncertainty of the source term is taken into account, it becomes clear that there is a significant likelihood that at all three areas of the Crownpoint project, radon-222 emissions generated by HRI's operation will, by themselves, exceed NRC regulatory limits. Given this high likelihood, the NRC Staff was not justified in concluding, in the FEIS, that HRI's emissions would be within regulatory limits.

Moreover, when taken together with the additional contribution of existing non-background sources at the Church Rock site, HRI is virtually certain to exceed regulatory limits. The combined radiation doses from existing and prospective sources of radon-

[23] As noted before, the uncertainty in the sampling and analysis could not be quantified. The factor of 5 between the base case and the upper and lower case is assumed to include this uncertainty.

222 and the existing external gamma radiation above background may be quite high. If one takes 2 pCi/l as the average radon concentration at Church Rock of which 0.2 pCi/l is the expected contribution from natural background, then the non-background activity of 1.8 pCi/l is equivalent to 900 mrem TEDE per year. Adding the above-background external gamma dose of ~300 mrem TEDE/yr, the total dose above background would be 1,200 mrem TEDE per year. Such high doses would pose a significant health threat to the neighboring population.

Equilibrium of radon-222 with daughter products

The results presented in the FEIS are based on calculations in which a partial equilibrium of radon-222 was calculated. The degree of equilibrium depends on the time between the release of radon-222 into the atmosphere and the exposure of individuals. In undisturbed air with little circulation, the short-lived daughter products will come into equilibrium with the parent radon with an effective half-life of about 30 minutes. A 25% equilibrium is attained after 15 minutes.

One way to address the equilibrium issue is by using the unit of Working Levels (WL) for the levels of radon-222 and its daughter products (progeny), as was done in the FEIS. One working level is equivalent to 100 pCi of radon-222 in equilibrium with its daughter products[24]. Thus, the 10 CFR Part 20 compliance criterion for radon-222 (with daughters present) of 0.1 pCi/l is equivalent to 0.001 WL[25]. If radon-222 is released without daughters present, buildup occurs rather rapidly. A radon-222 concentration of 0.4 pCi/l at 25% equilibrium (= 0.001 WL) is equivalent to a radon-222 concentration of 0.1 pCi/l at 100% equilibrium (= 0.001 WL). The MILDOS calculations submitted by HRI suggest a partial equilibrium (up to 50% in the one-mile radius around the facility). It is easy to see in figure 9 (upper case) that the annual average radon-222 concentrations can also exceed limits for 25% equilibrium of radon progeny (i.e. 0.4 pCi/l).

In contrast to this, my analysis was based on the assumption of a complete equilibrium of radon-222 with its daughters. It is appropriately conservative to assume 100% equilibrium because, as shown by the uncertainty assessment, a large part of the annual average expsoure to radon-222 is due to exposure over a few hours in a given year during which large annual releases conincide with situations where the releases are diluted only little by means of atmospheric dispersion. My calculations show that up to 50% of the annual average exposure can occur in a single hour. Such situations in turn are usually low wind speed situations in which the radon-222 daughter products have time to accumulate. This allows for equilibrium between radon-222 and its daughters.

In addition, even outdoor radon at a low equilibrium can produce concentrations with higher equilibrium if the radon-222 enters a dwelling or vehicle so that the buildup of the daughters is further allowed to continue. In such a case, the doses to an individual inside

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[24] National Commission on Radiological Protection (NCRP). Measurement of Radon and Radon Daughters in Air. NRCP Report No. 97. Bethesda, MD 1988, p. 94

[25] It should be noted that the limit used in the FEIS is 0.0011 WL (p. 4-85). This was apparently done by dividing the occupational limit (0.33 WL) by a factor of 300 as described in the introduction section of 10 CFR Part 20, Appendix B, Table 2. However, the limit for radon-222 in Table 2 is expressed in pCi/l, not in WL. The direct conversion yields a limit of 0.001 WL, a value that is about 9% lower than the one used in the FEIS. In my opinion, the stricter limit of the two values applies.

the dwelling will be larger if the radon as compared same air at an outdoor location. The precise buildup of radon-222 daughters depends on the air exchange rates and the deposition (plate-out) of particulate daughters. In short-term exposure events such as in this case, these uncertainties are of increased relevance as compared to long-term average exposures. Owing to these uncertainties, it is most appropriate to use the 0.1 pCi/l radon-222 compliance criterion for situations in which the equilibrium cannot be determined with sufficient accuracy.

5 Conclusions

The following conclusions can be drawn regarding the levels of radon in the Crownpoint and Church Rock area:

- The data strongly suggest that existing levels of radon in the Church Rock area are dominated by non-background sources.
- The measured levels of radon at Church Rock indicate that the existing contributions from non-background sources are in excess of the compliance level in 10 CFR Part 20 (100 millirem EDE per year, equivalent to 0.2 pCi/l of radon-222 with daughters present).
- The measured dose rates of external gamma radiation above natural background are in excess of the compliance levels in 10 CFR Part 20 as well.
- Any additional source of radon-222 at the Church Rock site would thus further increase the total dose above background from licensed and unlicensed sources.
- The radon-222 source term in the FEIS was based on measurements in groundwater at the proposed at the Unit 1 production site. The observed levels vary over three orders of magnitude. Averaging of such data is scientifically inappropriate. Given the wide range of data, a compliance assessment of doses resulting from radon-222 emissions has to properly address the uncertainty of the radon-222 source term and its implication for determining compliance with 10 CFR Part 20. The FEIS failed to provide such an analysis.
- This report presents a preliminary uncertainty analysis based on the data provided by HRI. It was assumed that the radon-222 data represents the variability of the hourly airborne source term. In addition, weather data from Gallup was used to determine the variability of the dispersion in the predominant wind direction (from WSW). The results of the analysis performed indicate a significant probability that the incremental radon-222 concentrations in the vicinity of the project will exceed the 10CFR20 compliance limits.
- Uncertainties regarding equilibrium of radon-222 are significant. In enclosed areas, radon-222 doses from the HRI operation to individual members of the public may be significantly greater than anticipated in the FEIS.
- Taken together, the radon-222 doses generated by the HRI project and contributions from existing radon sources and external gamma radiation may be quite high, and may therefore have significant impacts on human health in the immediate vicinity of the project.

In conclusion, on the basis of the available data, the FEIS fails to show that the proposed HRI project will comply with the 10 CFR Part 20 regulations regarding exposures to radon-222 and its progeny, or external gamma radiation. In addition, there is no discussion in the FEIS of the environmental and health effects of such noncompliance, which could be significant.

Table 1 Average concentrations of radon in outdoor air at Church Rock and other locations

Location	Sampling period	Radon concentration, pCi/l	Source
Church Rock	10/80 to 7/81	2.4 to 3.8 pCi/l	D'Appolonia Associates, 1981[26]
Church Rock	08/87 to 09/88	1.2 to 3.1 pCi/l	HRI, 1993[27]
Crownpoint	04/17/81 to 04/23/78 05/15/78 to 05/21/78	< 0.24 to < 0.60 pCi/l < 0.20 to < 0.53 pCi/l	HRI, 1992[28]
Crownpoint	04/78 to 02/79 04/79 to 03/80	0.10 to 0.13 pCi/l 0.15 to 0.17 pCi/l	Buhl et al, 1985[29]
Crownpoint	02/81 to 10/82	0.22 to 0.28 pCi/l	HRI, 1989[30]
Ambrosia Lake "background"	04/78 to 02/79 04/79 to 03/80	0.42 pCi/l 0.53 pCi/l	Buhl et al., 1985[31]

[26] D'Appolonia Associates. State of New Mexico Environmental Improvement Division, Uranium Mill License Renewal Application – Environmental Report, License NM-UNC-ML, UNC Mining and Milling, Church Rock Operations, Division of United Nuclear Operations, Volume I, December 1981; relevant portions attached as Exhibit E

[27] HRI Inc., Churchrock Project, Revised Environmental Report, March 1993; relevant portions attached as Exhibit D

[28] HRI, Inc. Environmental Assessment for HRI, Inc. Unit 1 Allotted Lease Program, Eastern Navajo District, New Mexico, submitted to U.S. Department of the Interior, Bureau of Indian Affairs (January 6, 1992) (ACN 9509080065), at 2-107 relevant portions attached as Exhibit B

[29] Buhl T. , Millard J., Baggett D. and Trevathan S., Radon and Radon Decay Product Concentrations in New Mexico's Uranium Mining and Milling District, Radiation Protection Bureau, New Mexico Health and Environmental Department, Final Report, March 1985; relevant portions attached as Exhibit C

[30] Hydro Resources Inc., Supplementary Environmental Report, New Mexico Uranium Mining Operations, April 20, 1989; relevant portions attached as Exhibit A

[31] Buhl T. , Millard J., Baggett D. and Trevathan S., Radon and Radon Decay Product Concentrations in New Mexico's Uranium Mining and Milling District, Radiation Protection Bureau, New Mexico Health and Environmental Department, Final Report, March 1985; relevant portions attached as Exhibit C

Table 2 Anthropogenic sources of radon in the Church Rock mining area[32]

Source	Period of Operation	Approx. Distance from HRI Church Rock ISL Mines
Foust No. 3 underground mine	1954-1955	2.5 to 3 miles S
Kerr-McGee Corp. Church Rock I Mine	1972-1983	3 to 3.5 miles NNE
Old Church Rock Mine (including contaminated soils, mine-water ponds and sealed shaft)	1960-1962; 1979-1982	0 to 0.5 miles N
Puerco River/Pipeline Arroyo	Received mine dewatering effluents in early 1960s and from during 1972-1986; impacted by accidental tailings wastewater discharge in July 1979	Ranging from 2 miles E, 3 miles SE, and 0.75 to 1.25 miles S
United Nuclear Corp. Church Rock Uranium Mill and Tailings Impoundment	1977-1983	2 to 2.5 miles NE
United Nuclear Corp. Northeast Church Rock Mine	1972-1983	2.5 to 3 miles ENE

[32] References: Hilpert LS, Uranium Resources of Northwestern New Mexico, U.S. Geological Survey Professional Paper 603 (1969), pg. 44; Chenowith WL, et al., Exploration in the Grants Uranium Region Since 1963, in Geology and Mineral Technology of the Grants Uranium Region 1979, New Mexico Bureau of Mines and Mineral Resources Memoir 38 (1980), pg. 17ff.; U.S. Department of the Interior, Uranium Development in the San Juan Basin Region, Final Report (Fall 1980), pg. I-12 to I-16; Canonie Environmental, Reclamation Engineering Services, Geohydrologic Report, Church Rock Site, Gallup New Mexico. Project RM 86-060-02, prepared for UNC Mining and Milling, Gallup New Mexico, May 1987

Table 3 Radionuclide concentration in well water from Unit 1 production area[33]

Well	Sample #	Date	Uranium mg/l	Ra-226 pCi/l	Gross alpha pCi/l	Gross beta pCi/l	Rn-222 pCi/l
15P29	1	05/11/82	0.002	19	48	27	49,000
	2	07/21/82	<0.001	15	31	27	32,000
16P1	1	06/02/82	0.003	26	110	140	360,000
	2	07/21/82	0.001	30	73	110	250,000
16P11	1	07/13/82	<0.001	1	5	5	550
	2	08/31/82	<0.001	0	2	4	1,000
16P15	1	05/18/82	<0.001	6	180	160	250,000
	2	07/21/82	0.002	57	120	130	
16P37	1	07/06/82	<0.001	0	3	6	520
	2	08/06/82	<0.001	1	5	4	930
16P43	1	05/11/82	0.002	71	300	130	320,000
	2	07/20/82	<0.001	68	230	100	230,000
16P44	1	06/22/82	<0.001	3	4	10	11,000
	2	08/25/82	0.01	3	6	11	8,400
16P57	1	05/11/82	0.01	2	610	510	1,100,000
	2	07/20/82	0.008	200	440	300	890,000
16P59	1	07/06/82	<0.001	14	50	44	30,000
	2	08/25/82	<0.001	17	51	52	54,000
16P65	1	07/01/82	<0.001	7	36	55	65,000
	2	08/06/82	<0.001	7	30	23	100,000
16P94	1	07/06/82	<0.001	1	0	5	480
	2	08/06/82	<0.001	2	4	4	690
16P96	1	06/21/82	<0.001	1	0	4	870
	2	08/25/82	<0.001	1	8	5	970
16P102	1	07/01/82	<0.001	2	4	30	2,200
	2	08/25/82	<0.001	0	7	4	1,000

[33] Source: HRI Inc., letter to U.S.NRC regarding water quality information for the Unit 1 property, June 18, 1996

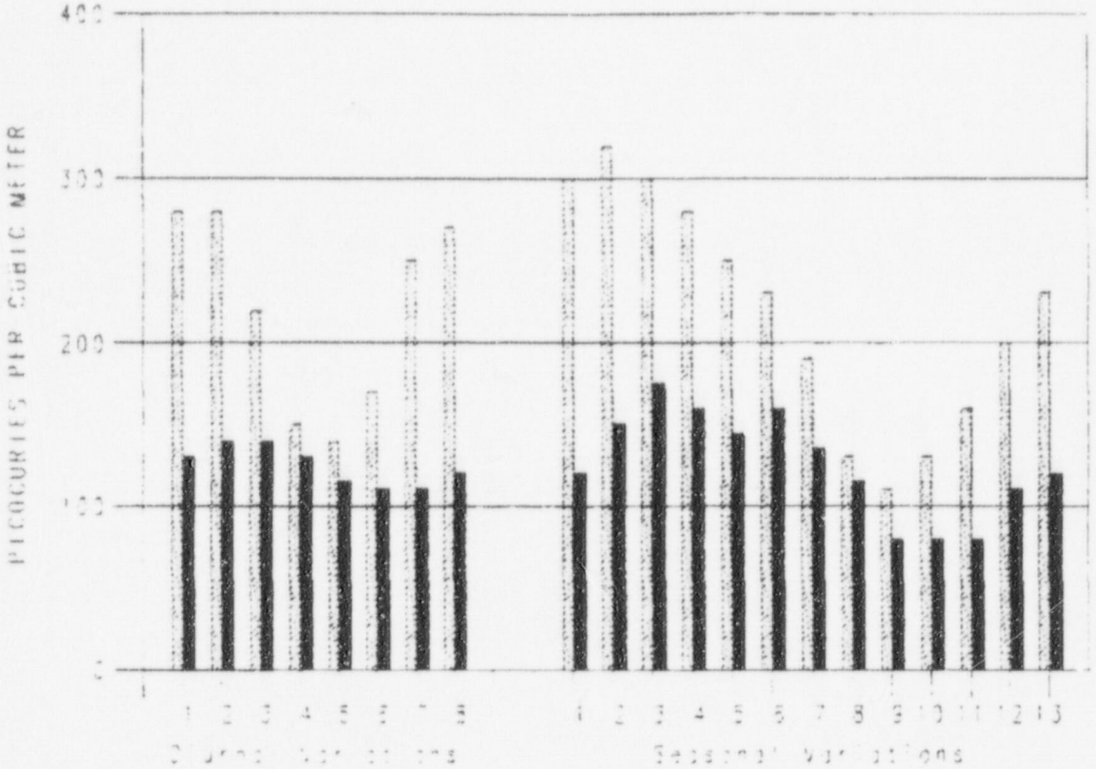

Fig. 6.1. Diurnal and seasonal variations in the outdoor radon concentrations at Chester, NJ and New York City.

Nine year (1977 to 1986) average variations in radon concentrations at Chester, NJ (hatched bars).

Four year (1983 to 1986) average variations in radon concentrations at New York, NY (solid bars).

The diurnal variations show the means for the 8 three-hour time periods. The seasonal variations show the means for the 13 four-week periods.

Diurnal Periods (EST)		Seasonal Periods*			
1	0000 to 0300	1	JUL 7–17	8	JAN 19–29
2	0300 to 0600	2	AUG 4–14	9	FEB 16–26
3	0600 to 0900	3	SEP 1–11	10	MAR 16–26
4	0900 to 1200	4	SEP 29–OCT 9	11	APR 13–23
5	1200 to 1500	5	OCT 27–NOV 6	12	MAY 11–21
6	1500 to 1800	6	NOV 24–DEC 4	13	JUN 8–18
7	1800 to 2100	7	DEC 22–JAN 1		
8	2100 to 2400				

* Denotes the range of starting dates of the periods over the nine-year interval.

Figure 1 Outdoor radon concentrations in Chester, NJ and New York City[34]

[34] National Commission on Radiological Protection (NCRP). Exposure of the Population in the United States and Canada from Natural Background Radiation. NRCP Report No. 94. Bethesda, MD 1987

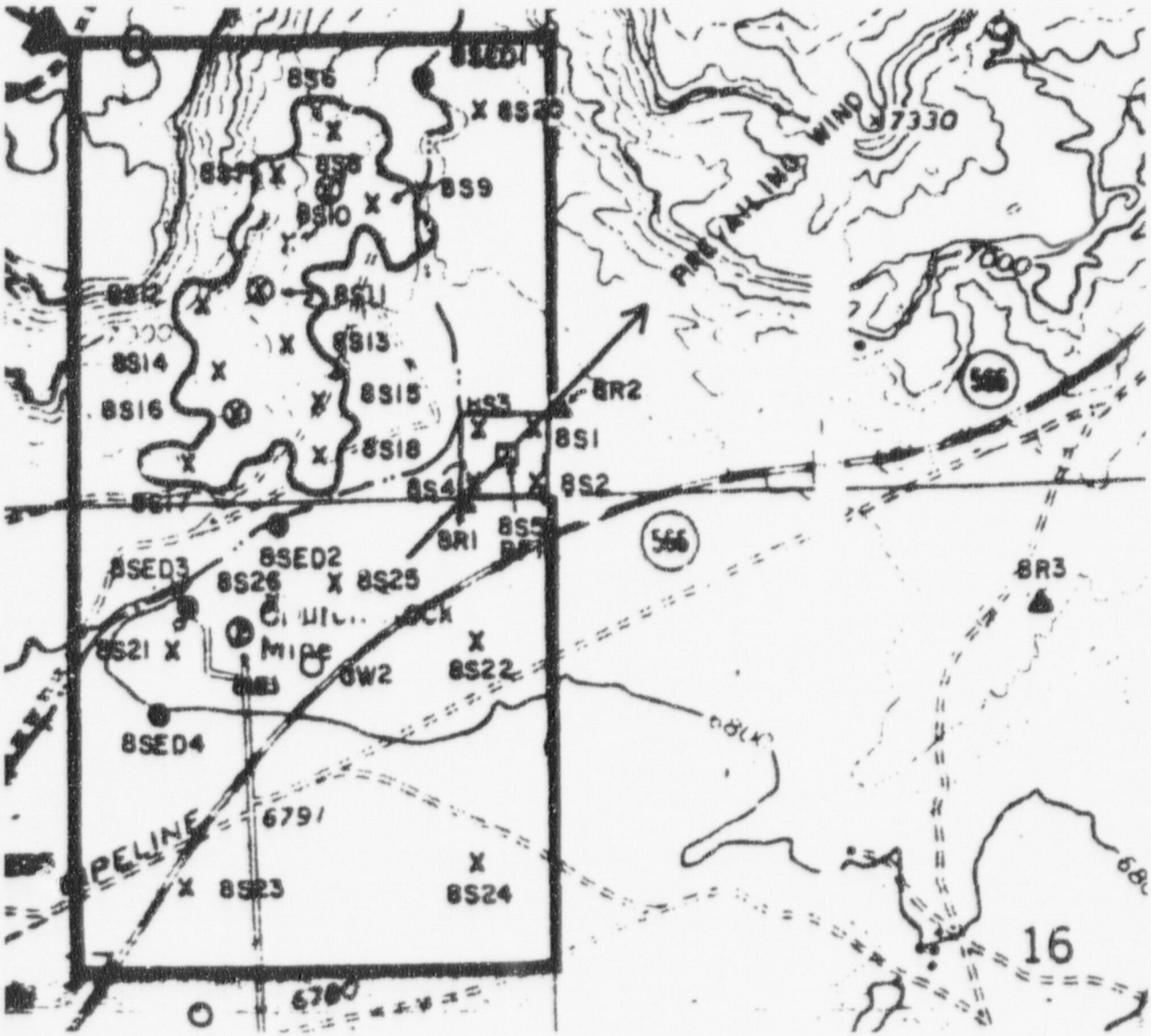

Figure 2 Sample location map of 1987 data; radon locations 8R1, 8R2 and 8R3 are marked by triangles
Source: Uranium Resources Inc., May 1987, Figure 2.9-2

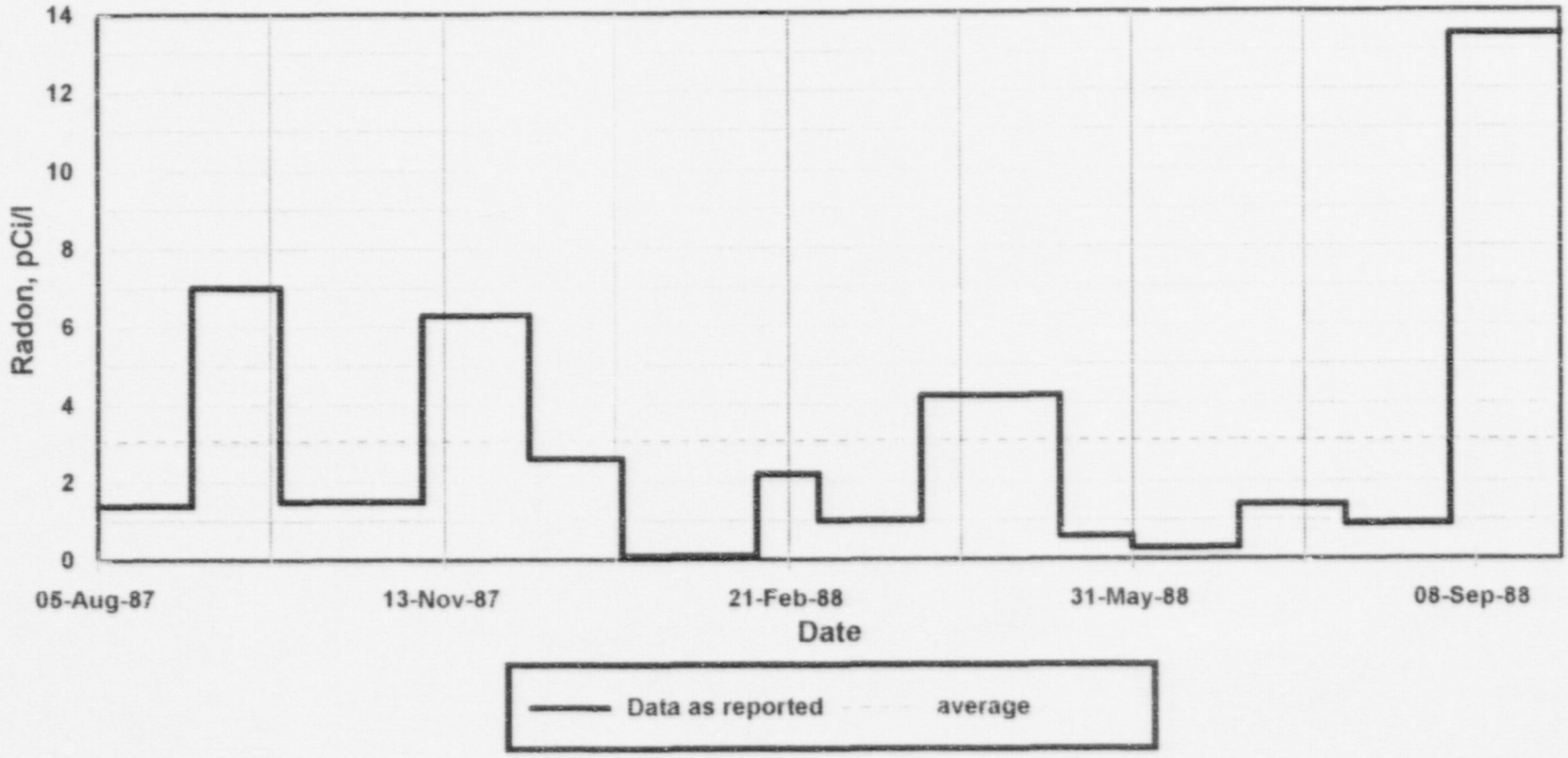

Figure 3 Outdoor radon concentrations in Church Rock area; sampling location "8R1", measurements using track etch devices

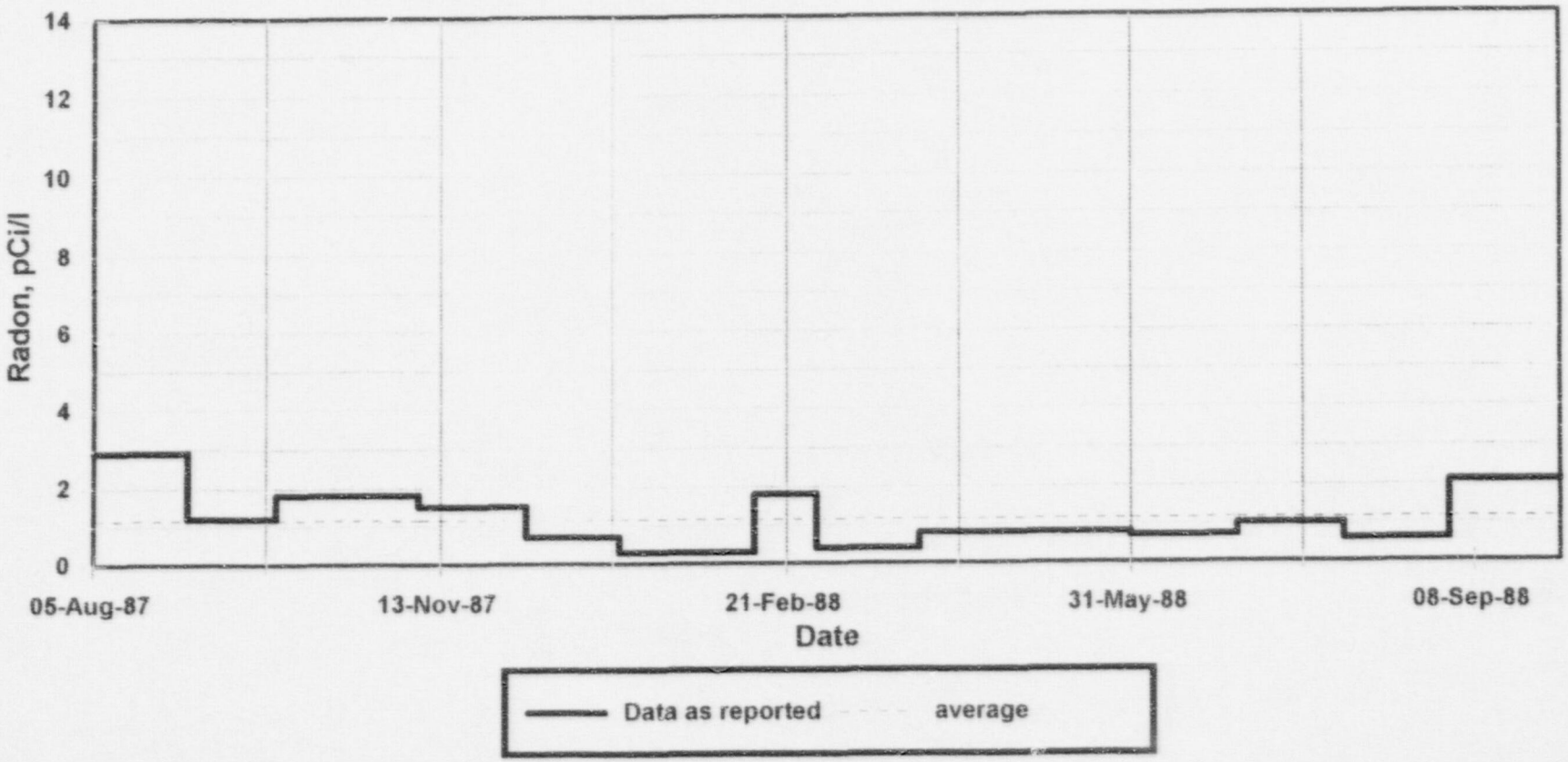

Figure 4 Outdoor radon concentrations in Church Rock area; sampling location "8R2", measurements using track etch devices

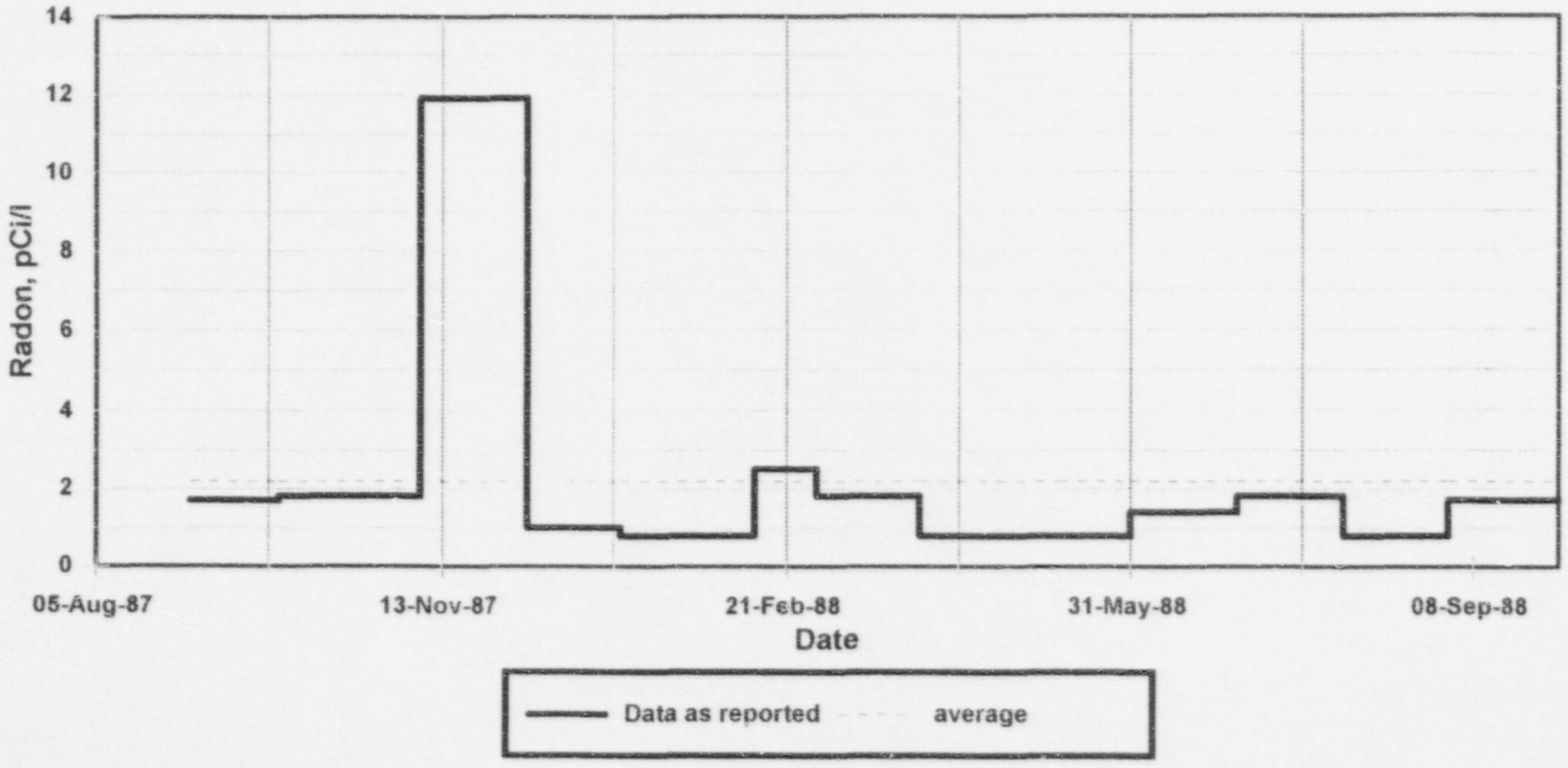

Figure 5 Outdoor radon concentrations in Church Rock area; sampling location "8R3", measurements using track etch devices

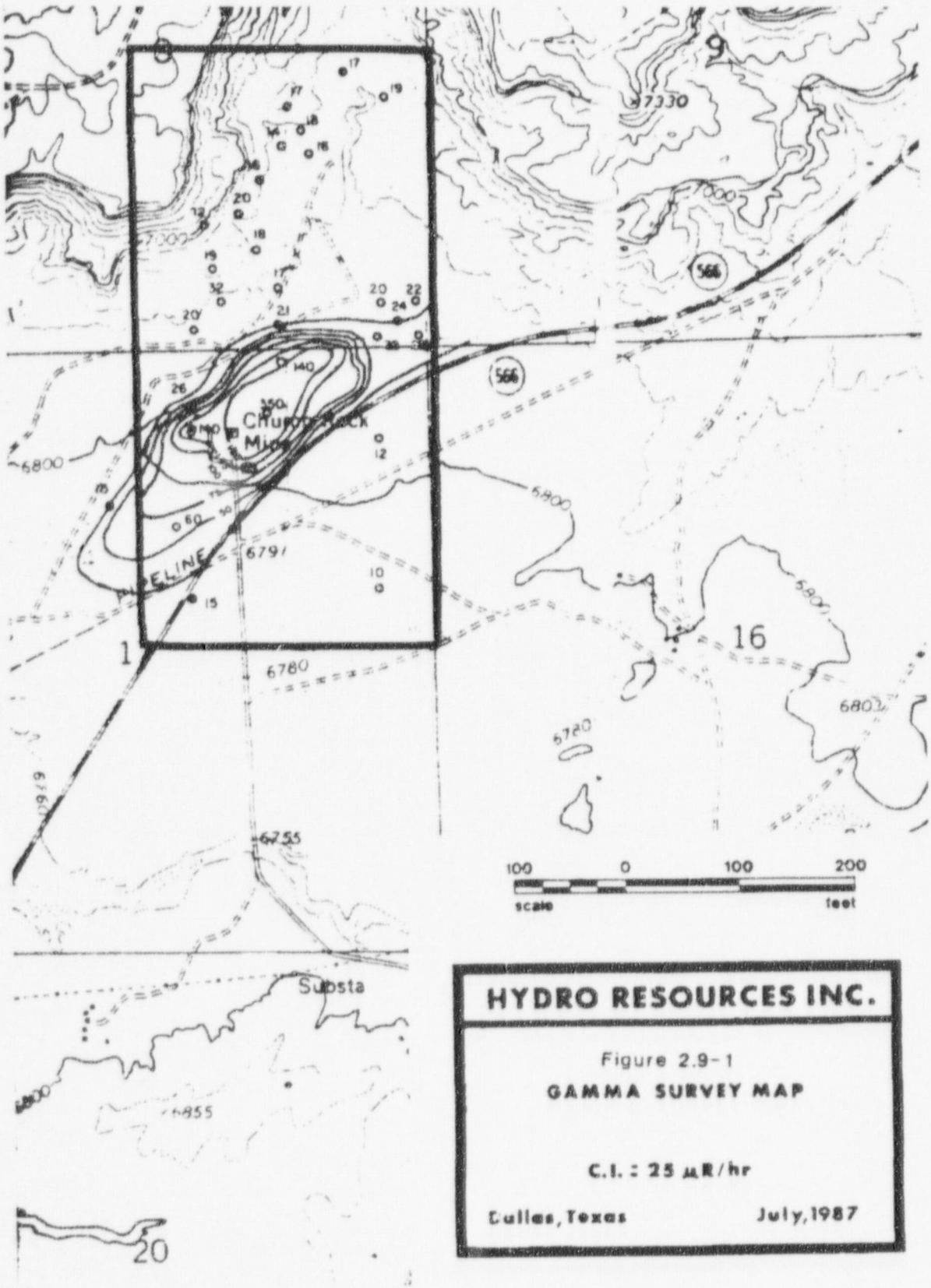

Figure 6 Gamma survey map at the Church Rock Site
Source: Hydro Resources Inc., July 1987, Figure 2.9-1

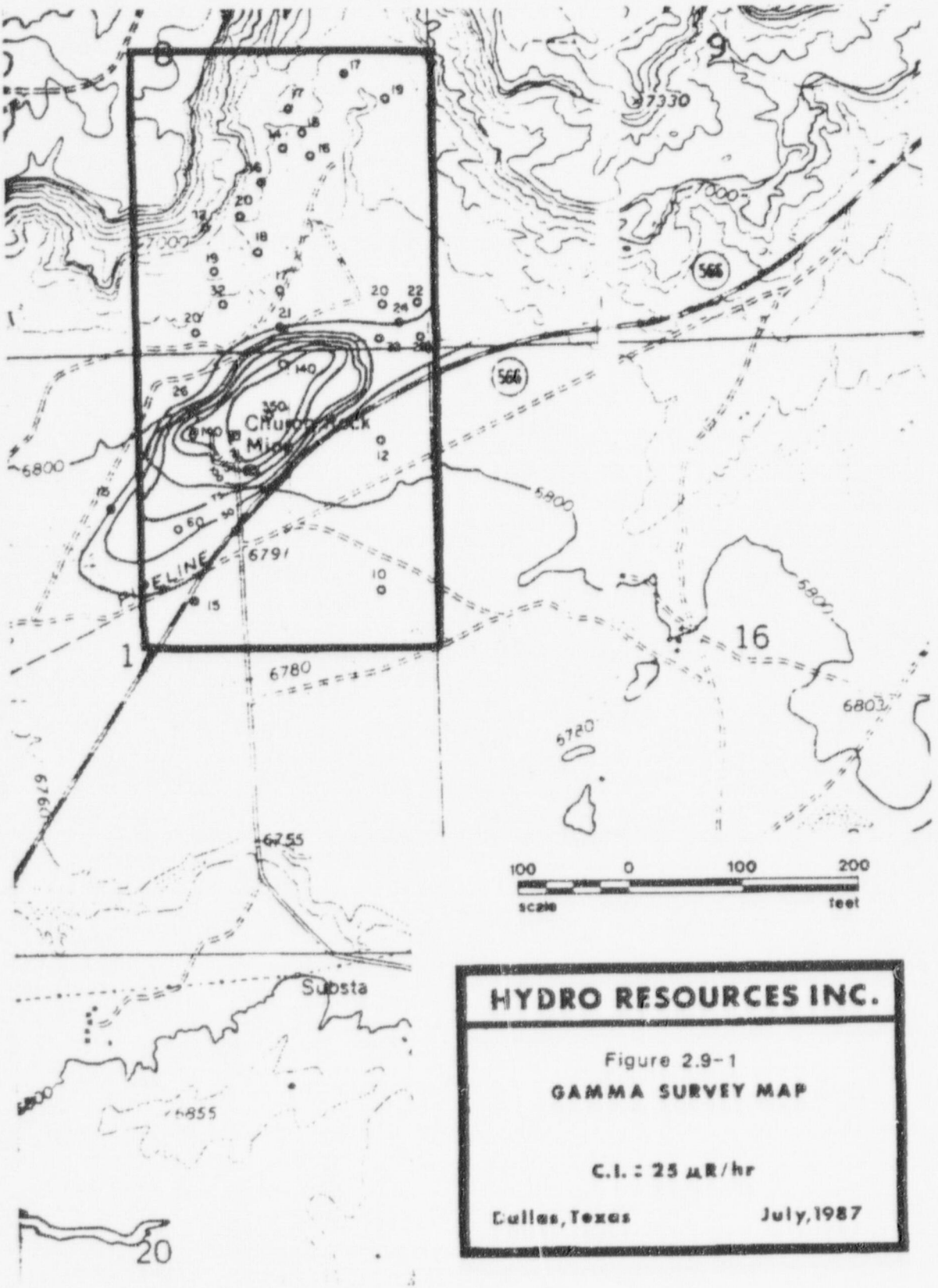

Figure 6 Gamma survey map at the Church Rock Site
Source: Hydro Resources Inc., July 1987, Figure 2.9-1

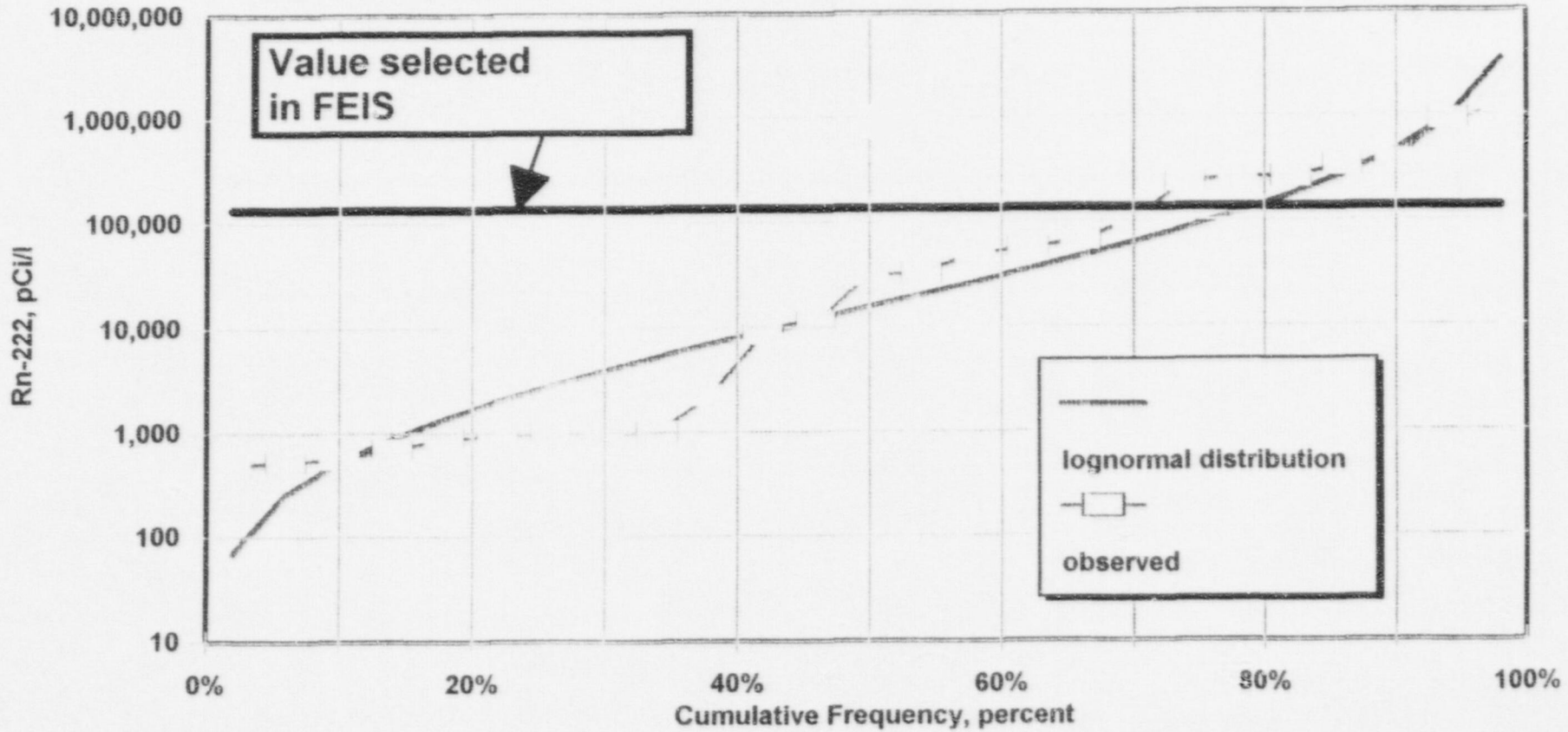

Figure 7 Cumulative frequency plot of Rn-222 concentration in well water from Unit 1 production area; comparison with lognormal fit of data

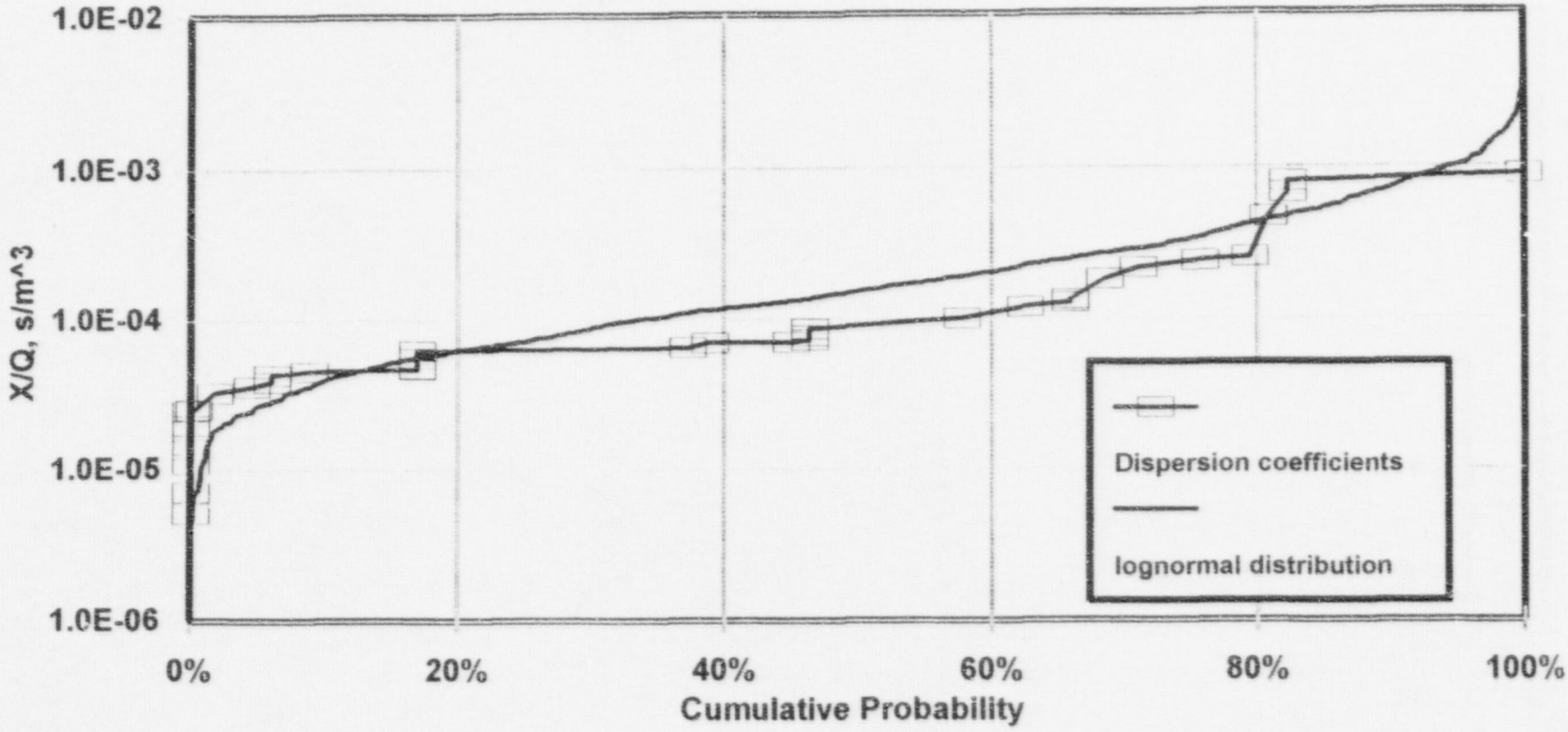

Figure 8 Cumulative frequency of dispersion coefficient χ/Q for wind direction WSW, distance 100 m, based on Gallup, NM weather data

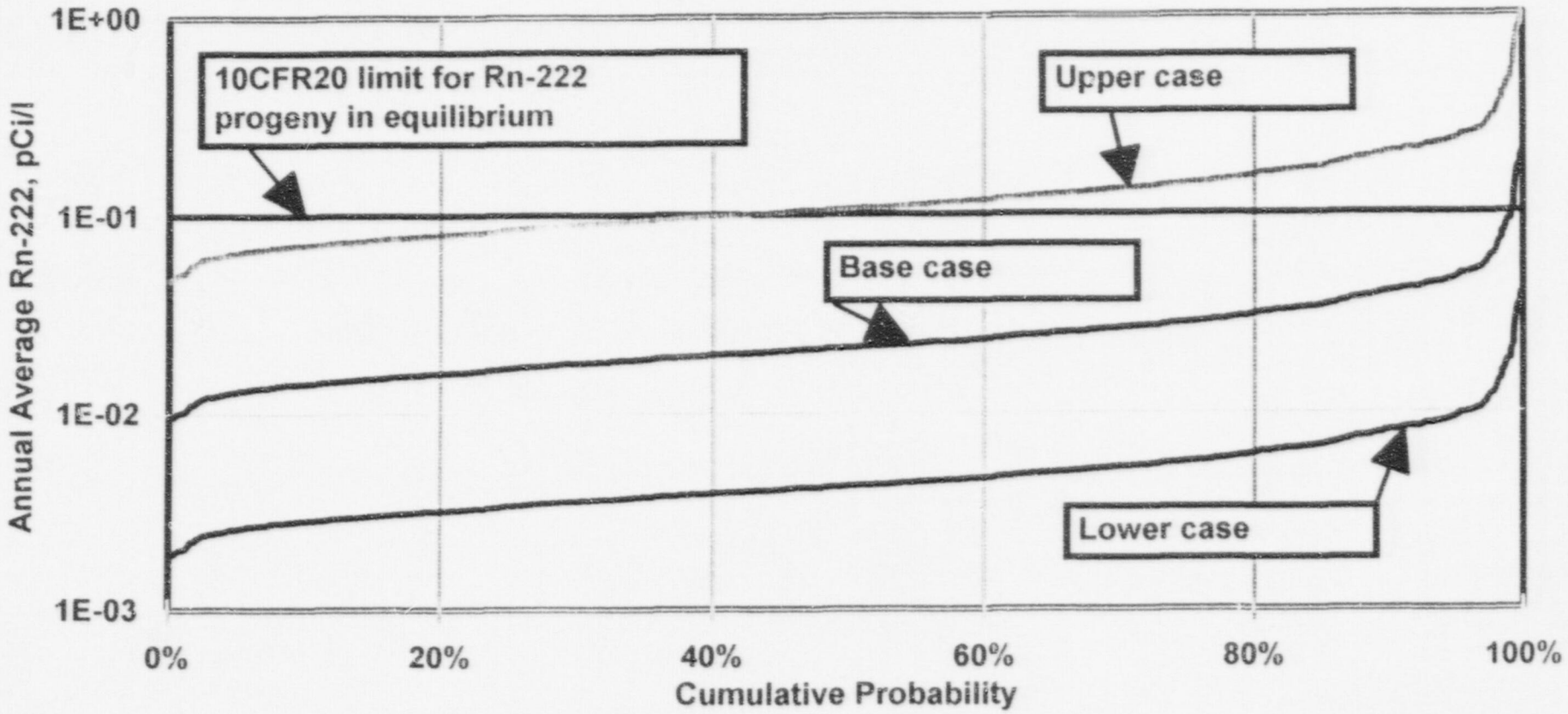

Figure 9 Predicted outdoor annual average Rn-222 concentration in 100 m ENE from HRI Unit 1
The parameters used in the uncertainty analysis are described in the text. The three scenarios are as follows:
(a) *Base case: annual average Rn-222 in groundwater of production wells is 133,000 pCi/l*
(b) *Lower case: annual average Rn-222 in groundwater of production wells assumed to be 27,000 pCi/l*
(c) *Upper case: annual average Rn-222 in groundwater of production wells assumed to be 670,000 pCi/l*

EXHIBIT A
to Franke Report

SUPPLEMENTARY ENVIRONMENTAL REPORT

NEW MEXICO URANIUM PRODUCTION OPERATIONS

HYDRO RESOURCES, INC.

April 20, 1989

w/ltr 5/8/89
89-0657

EXHIBIT A
to Franke Report

SUPPLEMENTARY ENVIRONMENTAL REPORT

NEW MEXICO URANIUM PRODUCTION OPERATIONS

HYDRO RESOURCES, INC.

April 20, 1989

w/ltr 5/5/89
89-0657

2.9 BACKGROUND RADIOLOGICAL FEATURES

2.9.1 Gamma Radiation

Gamma measurements were conducted during April 7, 1989 using a ludlum Micro R meter at each of the soil sampling sights shown on Figure 2.1-2. Table 2.9-1 lists all gamma measurements. Radon measurements were conducted from February, 1981 through September 1982 using charcoal canister type measurements. Sample stations are located 100 meters upwind and downwind (east and west). Results of the radon sampling are shown on Table 2.9-2. Gamma ranged from 12-15 to Rem/hr. Gamma measurements will be taken at greater density in wellfields and reported within the mining application.

2.9.2 Environmental Radionuclide

Uranium concentrations were obtained from vegetation at each gamma measurement location. Additional samples will be obtained at the radon sampling each season and analyzed for As, Cu, Mo, Se, Pb, V, Ra 226, Thorium 230, Lead 210 and Uranium, and will be submitted in the mining application. The uranium is within Table 2.9-3

Environmental uranium concentrations in soils were obtained from drainages in locations where gamma measurements were obtained and are presented on Table 2.9-4.

TABLE 2.9-2

CROWNPOINT PROJECT
BASELINE RADON

DATE	EAST	WEST
2/10/81-3/2	0.24	0.21
3/2-3/31	0.25	0.23
3/31-4/30	0.24	0.21
4/30-6/1	0.18	0.19
6/1-6/30	0.16	0.17
6/31-6/22	0.18	0.18
8/4-9/2	0.16	0.29
9/2-11/5	0.22	0.67
11/17-12/11	0.26	0.41
12/11-1/13/82	0.03	0.87
1/13-2/25	0.48	0.09
3/30-5/3	0.23	0.12
5/3-6/1	0.15	0.05
6/1-7/1	0.1	0.22
7/1-8/4	0.13	0.08
8/4-9/10	0.18	0.11
9/10-10/8	0.57	0.24

EXHIBIT B
to Franke Report

ENVIRONMENTAL ASSESSMENT
HRI,INC. UNIT 1 ALLOTTED LEASE PROGRAM
EASTERN NAVAJO DISTRICT, NEW MEXICO

SUBMITTED TO:
U.S. DEPARTMENT OF INTERIOR, BUREAU OF INDIAN AFFAIRS
WINDOW ROCK, ARIZONA

JANUARY 6, 1992

TR2AR

2.9 Background Radiological

Regional background radiation levels have been documented to establish a baseline from which the potential radiological impact of the project can be evaluated. Information on background radiation levels has been based on other uranium projects in the vicinity and from preoperational background radiological monitoring. Operational data from Crownpoint Pilot In-Situ Test at Section 9, T17N, R13W, is also included for comparison.

Exposure of individuals to radiation in the Crownpoint region results from the natural radiation in the environment as well as from human industrial activities. Natural radiation in the environment includes cosmic radiation and naturally occurring terrestrial radioactivity. Contributions due to human activities include the use of natural resources containing trace amounts of radioactivity, such as building materials, coal, oil, gas, and other raw materials used in industrial operatins; uranium removal and extraction; and medical diagnostics and treatment.

A significant source of the general population exposure to ionizing radiation is the natural radiation in the environment. This exposure to an individual is variable and is influenced by factors such as altitude, geology, minerology, topography, and personal living and working habits. This variation of exposure can often times exceed the exposure received from more publicized sources. For exampole, the dose from natural radiation to an individual in the United States ranges from 80-300 millirems per year (mrem/year). In addition, the average individual in the United States in 1977 received a medical X-ray exposure of 103 mremm/year. Other sources, such as nuclear power reactors and fallout, account for less than 10 mrem/year.

Exposure of populations to natural radiation sources has not received the attention which has been accorded to sources of less magnitude and ubiquity. Although some studies have shown no direct correlation of background radiation lwvels with observed health effects, the background exposure levels are less well defined than exposure from man-made sources. In order to determine the significance of the effects of incremental increases of radiation levels from man-made sources, it is important to carefully document the radioactivity concentration levels in the natural environment prior to man-made activities.

External natural radiation sources include cosmic radiation and radio-active elements in the earth's crust and in building materials. The surface of the earth is continually being bombarded by cosmic radiation. This radiation originates in interstellar space with some contribution from the sun. Upon striking the earth's upper atmosphere, primary cosmic radiations produce secondary radiations. Very few of the primary radiations penetrate as deep as the earth's surface. Thus, the secondary radiations are the major source of the cosmic radiation component of natural radiation.

Terrestrial radiation comes from naturally occurring radionuclides in the earth's crust. These materials contribute to human exposure by direct exposure and by indirect exposure through ingestion and inhalation. The radio-nuclides responsible for most of the natural radiation exposure include potassium-40, rubidium-87, and the uranium-238, uranium-235, and thrium-232 decay series. Radium-226, a member of the uranium-238 series, decays into radon-222, which is an inert noble gas with a half-life of 3.8 days. The half-life of radon-222 is long enough for it to diffuse through several feet of the earth's surface into the atmosphere. Since radon-222 decays into a series of short-lived alpha emitters, it can contribute to internal exposure through inhalation.

An additional increment of external exposure which accounts for less than five percent of the total, is due to the presence of radon isotopes andtheir radioactive decay products in the atmosphere. The radon flux to the atmosphere from a dry sandy soil containing one pCi radium-226/g is estimated to be 1.6 pCi/m_2-sec. Radon concentrations in the range of 500- 1000 pCi/m_3 are considered representative of natural background in a uranium mineralized region. Exposure to a radon concentration of 1000 pCi/m_3 on a continuous basis would result in a dose of 625 mrem/yr to the bronchial epithelium of the lung.

One source of internal exposure is the ingestion of natural radionuclides. Potassium-40 is the principal contributor to this internal dose, accounting for 65-90 percent of the dose from terrestrial radiation. Another significant internal emitter is carbon-14 (4-7 percent).

The retention of inhaled radioactive daughter products of radon isotopes is the primary source of lung dose to the general population. The inhalation of radon daughters requires special attention in the case of underground uranium miners. Exposure to occupants of residential dwellings can also be significant. A potential average lung dose of about 200 mrem/yr to occupants of unventilated wood dwellings and about 1800 mrem/yr to occupants of unventilated concrete buildings has been calculated.

The uranium-238 series produces the greatest part of radioactivity observed in natural water although the thorium-232 series may also be significant, locally. Alpha emitting substances in natural water are mainly isotopes of radium and radon, which are products of the uranium and thorium series. Beta and gamma emitting isotopes in water are primarily bismuth-214, bismuth-210, and thorium-234.

Natural radiation in the environment has been relatively constant for at least 10,000 years and probably much longer. However, changes in living habits have changed in such a way as to influence personal exposure. Populations have tended to migrate inland from coastal areas. This migration increases average geographical elevation of where the population resides and, hence its exposure to cosmic radiation. The previous outdoor agrarian society has largely been replaced by indoor work and life in urbanized-industrial centers; exposure has thus been increased in some instances because of the natural radioactivity of building materials. In other instances, buildings attenuate exposure to the outdoor terrestrial sources, thereby reducing exposure.

The available preoperational radiological monitoring program included analysis of air, soil, groundwater, flora, and fauna in the vicinity of an in-situ leach plant Section 16, T17N, R13W. The preoperational data base included information from the following: Crownpoint In-Situ Pilot Test (Section 9, T17N, R13W) and a one-year program at Section 12, T17N, R13W. In addition, operational data from the Crownpoint in-situ pilot test at Section 9, T17N, R13W, has been included. This data is within the appropriate standards and thus is not contributing significantly to the preoperational values. The results of these programs are discussed in the following sections.

2.9.1 Gamma Radiation, Radon-222 and Air Particulates

Gamma radiation, gaseous radon-222, and radioactive constituents of suspended particulate matter were monitored to establish background airborne radiation contamination levels. These results are shown in Tables 2.9-1 to 2.9-4.

Table 2.9-3

Concentrations of Radon-222 in Air
Mobil In-Situ Pilot Facility, Section 9, T17N, R13W
Preoperational (Mobil 1978)

(48-Hour Average)

Collection Location	Radon Concentration Dates	(pCi/l)
West Site Boundary	4/17-19/78 4/19-21/78 4/21-23/78	< 0.24
	5/15-17/78 5/17-19/78 5/19-21/78	< 0.53
South Site	4/17-19/78 4/19-21/78 4/21-23/78	< 0.60
	5/15-17/78 5/17-19/78 5/19-21/78	< 0.20
East Site	4/17-19/78 4/19-21/78 4/21-23/78	< 0.31
	5/15-17/78 5/17-19/78 5/19-21/78	< 0.21

EXHIBIT C
to Franke Report

RADON AND RADON DECAY PRODUCT CONCENTRATIONS IN NEW MEXICO'S URANIUM MINING AND MILLING DISTRICT

Thomas Buhl
Jere Millard
David Baggett
Sue Trevathan

Radiation Protection Bureau
Environmental Improvement Division
New Mexico Health and Environment Department

FINAL REPORT
March 1985

EXECUTIVE SUMMARY

Elevated radiation levels associated with uranium mining and milling activities have been of concern in recent years. Reports concerning uranium mill tailings in Grand Junction, Colorado and Salt Lake City, Utah have demonstrated that increased concentrations of airborne radioactivity occur in areas surrounding tailings piles. In addition, uranium mine releases of radioactivity have been shown to be of concern not only to mining personnel but to indigenous populations through the venting of particulates and radioactive radon-222 gas. Increased risk of lung cancer among uranium miners exposed to high concentrations of radon gas and its radioactive decay products has been documented. While elevated radon and radon decay product concentrations are much lower in the areas surrounding uranium mines and mills, the New Mexico Environmental Improvement Division (NMEID) remains concerned about potential health hazards to the public health resulting from exposures to radiation from uranium mining and milling activities.

In 1977, the New Mexico Legislature appropriated $100,000 to the NMEID for a "program to prevent or abate harm to the environment from radiation or chemicals directly or indirectly caused by mine spoil piles and mine stock piles and tailings from uranium mills..." To support this legislative mandate a one year monitoring study was undertaken to determine (1) sources of high concentrations of airborne radioactivity in uranium producing areas, (2) background radioactivity levels as well as levels associated with milling facilities and mines, (3) if New Mexico standards are being exceeded, (4) potential future problem areas in view of the then-rapid expansion of the uranium industry and (5) the need for further regulation development and remedial action. This study was later extended an additional year.

Specifically, the two year NMEID program collected and measured over 1700 individual outdoor radon air samples from 33 sites, and documented radon decay product concentrations inside buildings and homes at 18 locations in the Grants Mineral Belt. Radon and radon decay product data were analyzed statistically and compared with both background and current state and federal standards. External radiation exposure rates were also measured at all radon and radon decay product sampling locations.

Radon concentration measured near uranium milling facilities not located near uranium mines were not found to exceed New Mexico Radiation Protection Regulations (NMRPR) for an individual. These regulations exclude all contributions from natural background. In general, these levels were also below the more restrictive standard for a population which is one-third of the standard for an individual. Several values, however, were close to or above the population limit. Consequently, monitoring should continue in housing developments and small communities near uranium facilities to verify that these more restrictive radiation standards for a population continue to be met in the future. In addition, since only radon was considered in making this assessment, monitoring results from all other existing exposure pathways must be included to determine overall compliance with regulatory limits.

Uranium mines are not subject to the NMRPR. For purposes of comparison, however, the NMRPR concentration limits were used as health guidelines to gauge ambient radon concentrations resulting from activities including mining.

Since background must be subtracted from the measured radon concentrations, estimates of net concentration are difficult to make because of the technical problem of determining radon background in the heavily developed Ambrosia Lake area. The estimates presented are believed to be realistic based on background measurements made elsewhere and on the results of computer modeling.

Measured radon concentrations in air near uranium mines were found to be above radon health guidelines based on the NMRPR for an individual member of the public at three of nine locations in the Ambrosia Lake region in the Grants Mineral Belt. Radon levels at these three locations were roughly twice the concentration limit for one year of the study. The total radon inventory was partitioned based on estimates of the fraction of the radon from natural background, uranium mining and milling. It was estimated that 80% of the total radon released per year at Ambrosia Lake came from mining activities, 4% from milling activities and 16% from natural background sources.

While elevated radon concentrations indicate the potential for excessive exposure to radiation and the necessity for future monitoring activities, actual radiation exposures depend on a number of factors. These factors include meteorological conditions, building materials, proximity to radiation sources, air exchange rates in nearby structures and duration of exposure. Indoor radon decay product measurements show that radiation exposures could range from near background to above health guidelines. However, due to the difficulty in estimating above background radon decay product levels indoors, it is difficult to determine if health guidelines have been exceeded. Because of the existing potential for exposure to radon decay products indoors, industry has made a concerted effort to remove as many residences from Ambrosia Lake as possible. The population has decreased from approximately 100-150 residents at the time of this study to less than five in 1985.

For the purposes of planning and regulation development, the lifetime risk of a radiation induced cancer death was estimated for a hypothetical individual who is exposed to the measured radon levels at Ambrosia Lake. This estimate was made to evaluate the need for regulation of environmental impacts from uranium mining.

The lifetime risk of premature lung cancer was one chance in 1000 to one chance in 10,000 per year of exposure for the average two-year Ambrosia Lake radon concentration of 4.0 pCi/l. The corresponding risk for 6.4 pCi/l, the highest yearly average measured in the NMEID study, was one chance in 600 to one chance in 6000 per year of exposure. Measured background radon concentrations averaged approximately 0.5 pCi/l and corresponded to a lifetime risk of one chance in 8000 to one chance in 80,000 per year of exposure.

Since unlicensed sources have been shown to contribute the majority of radon compared to all other sources, modification of the New Mexico Radiation Protection Regulations to include uranium mining must be considered. In addition, every

effort should be made to avoid future siting of mine vents near populated areas. If this situation occurs, radon levels should be continuously monitored at all critical locations. Clearly, it would be inadvisable to locate any future housing in areas determined to be borderline or in excess of radiation protection limits. It should be further recognized that documentation of background levels in areas of proposed uranium extraction is critical to the NMEID for protection of the public health through its regulatory authority and that a clear definition of "background" be stated in the radiation regulations.

TABLE 3.1 First Year Radon Averages by Station (pCi/l)

Station	Mean	Standard Deviation	Standard Error	Sample Number	P(Normal)[a]	P(Log-Normal)[a]
201	1.12	1.15	.28	17	LT.01	.268
202	1.32	.99	.22	20	.164	.783
203	1.92	1.26	.28	20	LT.01	LT.01
204	2.01	1.35	.34	16	LT.01	.456
205	1.55	1.14	.28	17	LT.01	.154
206	1.18	1.05	.24	19	LT.01	.830
208	1.10	.97	.27	13	.049	.428
209	.72	.69	.16	18	.01	.357
210	1.55	1.31	.30	19	.01	.074
211	.44	.46	.10	20	.01	.822
212	.36	.45	.10	21	.01	.064
302	1.37	.70	.16	19	.354	.877
305	.76	.68	.16	19	.034	.354
307	.63	.73	.18	17	.01	.588
309	.30	.29	.07	19	.18	0.521
310	.41	.49	.12	17	.01	.827
313	.48	.37	.08	20	.017	.056
315	.57	.55	.12	22	LT.01	.837
401	1.02	.25	.06	20	.764	.108
402	3.15	1.66	.35	22	.548	.168
403	3.47	1.87	.42	20	LT.01	.540
406	2.96	1.85	.44	18	.566	LT.01
407	2.01	1.11	.26	18	.043.	520
408	4.12	3.03	.66	21	.188	LT.01
409	3.59	3.32	.76	19	LT.01	.388
411	.91	.55	.13	19	.477	.081
412	4.23	4.56	1.27	13	LT.01	.427
414	1.50	1.17	.27	19	.037	.469
500	.13	.08	.05	3	.640	.975
501	.10	.03	.02	3	.154	.122
502	.10	.05	.03	3	.05	.069
Background[b]	.57	.69	.06	122	LT.01	GT.15
Selected Bkg[c]	.42	.34	.07	25	LT.01	.746
Ambrosia Lake[d]	3.20	2.53	.24	110	LT.01	.023
Anaconda[e]	1.06	.75	.12	38	LT.07	LT.01
HMC[f]	1.83	1.24	.17	53	LT.01	LT.01

(a) Probability that a normal/log-normal distribution would have a test statistic larger than that calculated for the data at each station. If the value is less than 0.05 the distribution is not normal/log-normal using the 95% level of significance.
(b) Composed of all samples taken at stations 201, 209, 211, 212, 307, 313, 500, 501, 502.
(c) 25 samples chosen at random from all individual background samples.
(d) Pooled sampled taken at stations 402, 403, 406, 407, 409, 412.
(e) Pooled samples taken at stations 302, 305.
(f) Pooled samples taken at stations 203, 204, 205.

TABLE 3.2 Second Year Radon Averages by Station (pCi/l)

Station	Mean	Standard Deviation	Standard Error	Sample Number	P(Normal)[a]	P(Log-Norma
201	.81	.75	.17	20	.011	.544
202	.89	.78	.17	21	LT.01	.320
203	1.51	1.11	.24	22	LT.01	.409
204	1.89	1.00	.21	23	.357	.826
205	1.12	.83	.18	22	LT.01	.631
206	.93	.83	.19	20	.015	.210
208	.84	.64	.14	20	.016	.917
209	.79	.57	.12	23	.072	.167
210	1.41	1.35	.31	19	.015	LT.01
211	.71	.81	.17	23	LT.01	.249
212	.61	.59	.14	18	.042	.266
302	.78	.50	.11	21	.404	.097
305	.95	.76	.17	21	LT.01	.976
307	.55	.53	.12	21	LT.01	.024
309	.21	.13	.03	21	.386	LT.01
310	.36	.28	.06	20	.156	.061
313	.47	.51	.11	23	LT.01	.536
315	.49	.37	.08	24	.030	.048
401	1.18	.43	.10	19	.303	0.12
402	6.40	3.28	.66	25	LT.01	.914
403	5.70	2.23	.50	20	.213	.096
406	3.40	2.00	.44	21	.096	LT.01
407	3.23	1.55	.32	23	.773	.035
408	5.77	3.59	.77	22	.470	.246
409	5.43	3.58	.75	23	.360	LT.01
411	1.10	.78	.16	24	.193	.051
412	3.74	2.53	.52	24	.330	LT.01
414	1.69	1.23	.26	22	.050	.436
415	.14	.22	.05	19	LT.01	.482
500	.15	.12	.03	16	.806	.675
501	.17	.13	.03	15	.087	.081
502	.14	.10	.03	9	LT.01	.456
Background[b]	.50	.58	.04	187	LT.01	GT.15
Selected Bkg[c]	.53	.73	.15	25	LT.01	.546
Ambrosia Lake[d]	4.66	2.89	.25	136	.091	LT.01
Anaconda[e]	.87	.64	.10	42	LT.01	.407
HMC[f]	1.51	1.02	.12	67	LT.01	GT.15

(a) Probability that a normal/log-normal distribution would have a test statistic larger than that calculated for the data at each station. If the value is less than 0.05 the distribution is not normal/log-normal using the 95% level of significance.
(b) Composed of all samples taken at stations 201, 209, 211, 212, 307, 313, 415, 500, 501, 502.
(c) 25 samples chosen at random from all individual background samples.
(d) Pooled samples taken at stations 402, 403, 406, 407, 409, 412.
(e) Pooled samples taken at stations 302, 305.
(f) Pooled samples taken at stations 203, 204, 205.

distribution. A Kolmogorov-Smirnov test for normality and log-normality was performed on the data from each sampling site for each year of sampling (21). P-values for these tests are shown in Tables 3.1. and 3.2.

As can be seen from Tables 3.1 and 3.2, the data favor, although not conclusively, the log-normal distribution. Fifty-one of the 63 tests (81%) had a P (log-normal) value greater than 0.05, while only 27 (43%) had a P (normal) greater than 0.05. While this indicates that the individual station distributions may have the same general log-normal shape, the failure rate is slightly greater than what one might expect. It was therefore felt more appropriate to use non-parametric tests, which are slightly less powerful than parametric tests, but do not require any distributional assumptions.

Two types of non-parametric tests were used to compare data. A Kruskal-Wallis test (non-parametric one-way analysis of variance) determined if data collected at several different stations could be shown to come from the same population. This test indicated, for example, if radon data taken at different background stations were from distinct populations or not.

The second non-parametric test used was the Wilcoxon rank sum test. This test determined if data taken from two locations, such as background and Ambrosia Lake, were from the same population.

In addition to non-parametric tests, a t-test was also performed to provide a comparison with a more generally used test. Even though the t-test is parametric, it is known to be robust in handling non-normal data (20, 40, 41).

4.2 BACKGROUND RADIATION LEVELS

4.2.1 Radon

Measurements were taken in the Grants Mineral Belt at ten locations believed to be relatively unaffected by emissions from monitored facilities. Values measured at these stations were used to estimate the natural radon environment prior to uranium development. Average background radon concentrations were found to be 0.57 ± 0.06 pCi/l and 0.50 ± 0.04 pCi/l for the first and second year of monitoring. Measurements taken near uranium facilities were then compared with background levels in order to see if any statistically significant increase in radiation levels had occurred. Background radon stations were located at Grants (station 212), Milan (211), San Mateo (415), Crownpoint (500 and 501), Bluewater Lake (502), and at four sampling sites 1.5 miles from a uranium facility (201,209, 307 and 313), as shown on Figure 3.1.

A Kruskal-Wallis test was performed with a null hypothesis that no difference existed between radon concentrations at background locations. The test result gave a probability less than 0.001, and therefore the null hypothesis was rejected. The data indicated that there were statistically significant differences in background radon concentrations measured at various locations within the Grants Mineral Belt. An inspection of the data showed that station 201 was consistently elevated above other stations, while stations 415, 500, 501 and 502 were consistently below the average. Omitting these five stations from

EXHIBIT D
to Franke Report

HRI, INC.

CHURCHROCK PROJECT

REVISED ENVIRONMENTAL REPORT

MARCH, 1993

2.9 BACKGROUND RADIOLOGICAL FEATURES

2.9.1 Gamma Radiation

Gamma measurements were conducted during the survey in the spring of 1987 using a Ludlum scintillator at the ground surface. Figure 2.9-1 shows the gamma activity level in mRem/hr. Gamma ranged from 12 mRem/hr. to 350 mRem/hr. with the higher concentration generally found in association with previous uranium mining activity.

2.9.2 Environmental Radionuclide

Radionuclide concentration in vegetation is covered in Section 2.8.

Environmental radionuclide concentrations in soil were determined by obtaining 26 soil samples in the plant, wellfield and license area and analyzing the soils for U, Ra226, Pb210 and Th230. Sample locations are shown on Figure 2.9-2. The results at this sampling program are within Table 2.9-1. Generally speaking, the four nuclide concentrations are proportional for a given sample. If U is high, then Ra226, Pb210 and Th230 also are high. As was the case with gamma activity, higher nuclide concentrations are generally found in association with previous mining activity. One sample, 8S-16, was anomolously high in nuclide concentration, but not in an area associated with previous mining. This may be a local anomoly, or may be one of many small local occurrences related to exploration activity. HRI will survey more exploration sites before mining to determine if, in fact, many small local areas of local areas of high nuclide concentration exist.

Seven sediment samples were obtained...six in the arroyo, which dissect the license area, and one in a pond which was associated with the prefious mining activity. Analysis of all creek samples (Table 2.9-2) were revealed similar concentrations of radionuclides and other metals. The pond samples showed higher nuclide concentrates.

Radon measurements began in August using Tract Etch measurement devices. ample stations were located 100 meters upwind and downwind of the proposed process facility, and at the closest residence downwind. Results of the Radon sampling program are shown on Table 2.9-3. Monthly sampling will continue until one full year of measurements are obtained.

Table 2.9-3

Churchrock Project
Baseline Radon

Month	8R1*	8R2*	8R3*
08-05-87 - 09-01-87	1.4	2.9	-
09-01-87 - 09-27-87	7.0	1.2	1.7
09-27-87 - 11-07-87	1.5	1.8	1.8
11-07-87 - 12-08-87	6.3	1.5	11.9
12-08-87 - 01-04-88	2.6	.7	1.0
01-04-88 - 02-12-88	.1	.3	.8
02-12-88 - 03-01-88	2.2	1.8	2.5
03-01-88 - 03-31-88	1.0	.4	1.8
03-31-88 - 05-10-88	4.2	.8	.8
05-10-88 - 05-31-88	.6	.8	.8
05-31-88 - 07-01-88	.3	.7	1.4
07-01-88 - 08-01-88	1.4	1.0	1.8
08-01-88 - 09-01-88	.9	.6	.8
09-01-88 - 10-03-88	13.4	2.1	1.7

* All values in pC/l

EXHIBIT E
to Franke Report

Project No. NM81-433
Dec. 81

Volume I
Text and Tables

State of New Mexico Environmental Improvement Division Uranium Mill License Renewal Application-Environmental Report License No. NM-UNC-ML

UNC Mining and Milling
Church Rock Operations
Division of United Nuclear Corporation

Church Rock Mill
Gallup, New Mexico

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10/29/81	APPROVED BY	MGK	12/21/81	

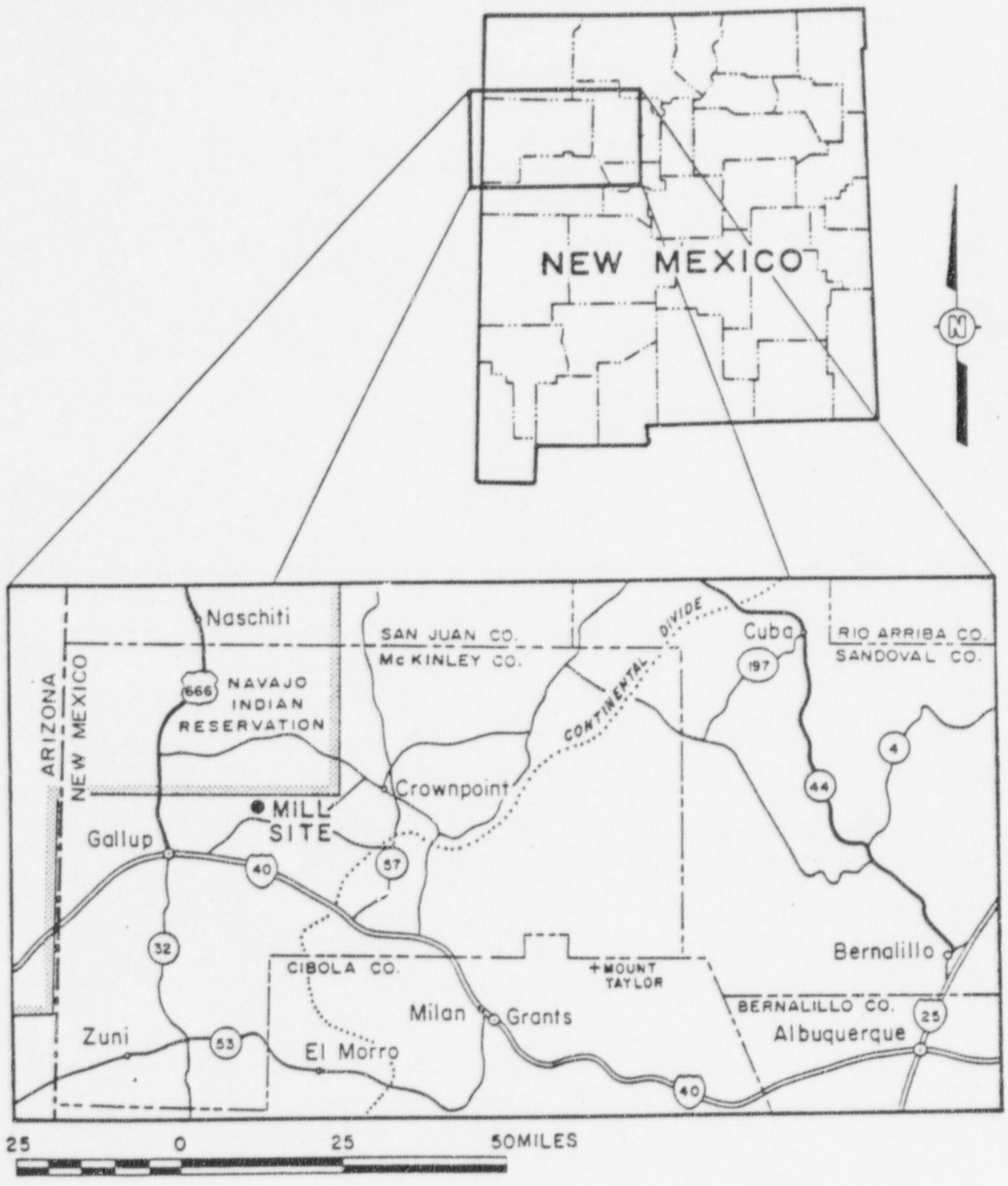


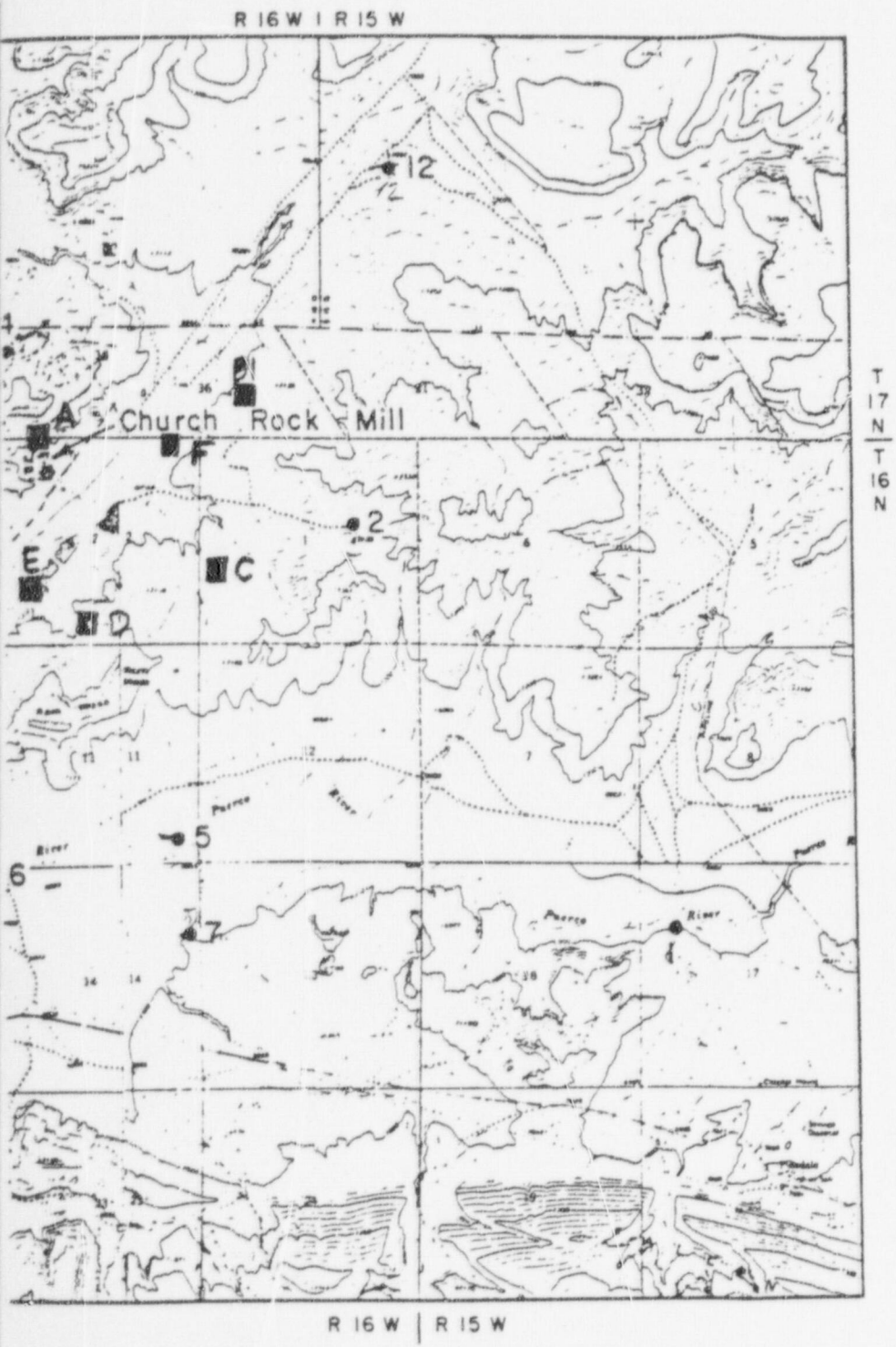
FIGURE A1-1

SITE LOCATION MAP

PREPARED FOR

UNC MINING AND MILLING
CHURCH ROCK OPERATIONS

D'APPOLONIA



LEGEND

● 6 WELL LOCATION

▲ 4 SPRING LOCATION

N

1 0 1 2 KM

1 0 1 MILE

SCALE

NOTE:
SEE TABLE B3.15 FOR WELL AND SPRING CHARACTERISTICS.

A ■ Rd-222 monitoring stations from Fig. C8-1, Table D-3

FIGURE B3-8

EXISTING WELL AND SPRING LOCATIONS

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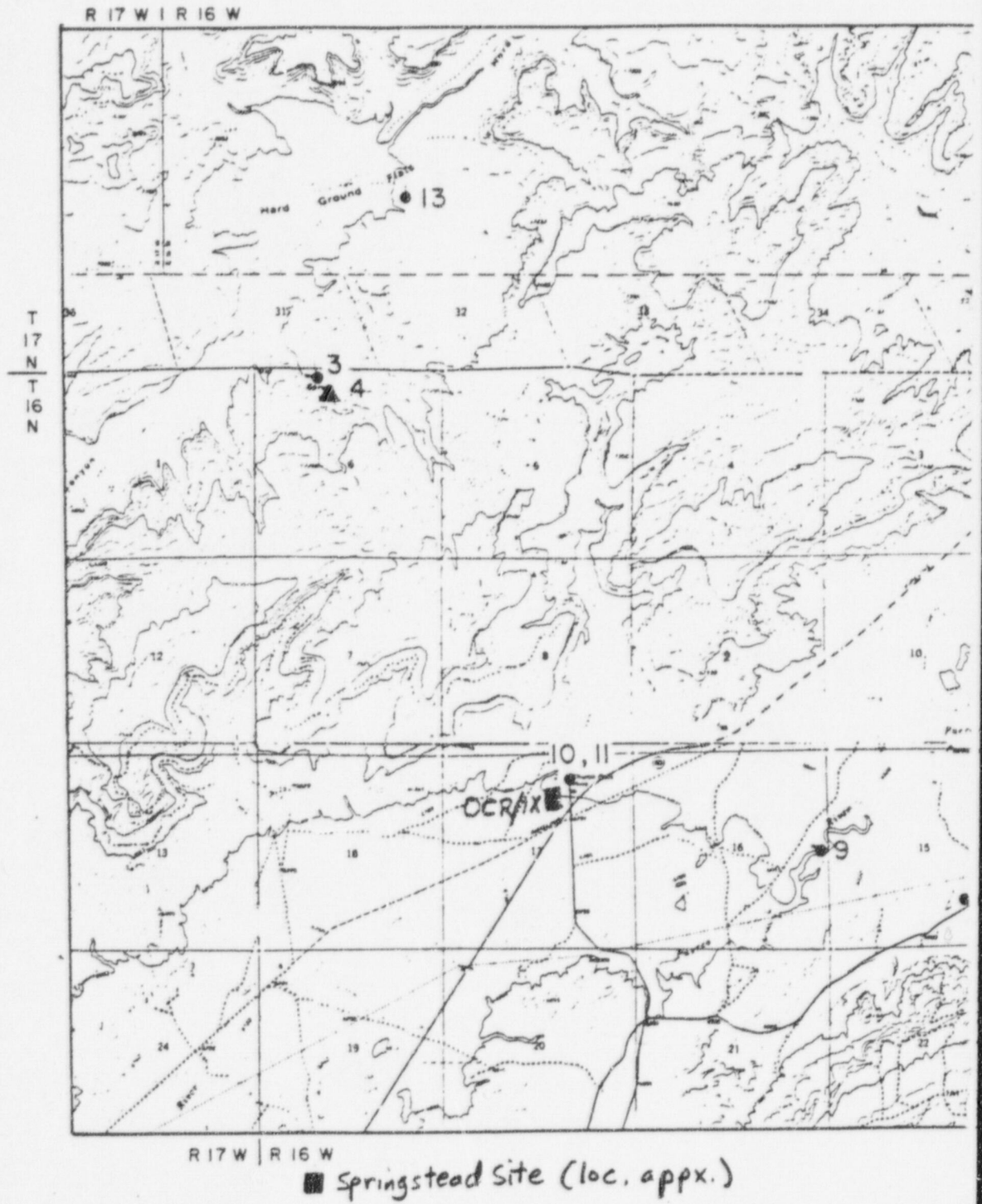
DAMPLADELA

DRAWN BY	EF	CHECKED BY	WHC	DRAWING NUMBER NM81-433-B2
	11/4/81	APPROVED BY	KSK	12/21/81



REFERENCES: USGS 7.5 MINUTE SERIES QUADRANGLE MAPS PINEDALE, NEW MEXICO (1963); OAK SPRING, NEW MEXICO (1963); HARD GROUND FLATS, NEW MEXICO (1979); CHURCH ROCK, NEW MEXICO (1979)

C4.3 OCCUPATIONAL DOSE

UNC has gathered an extensive body of data over the past five years to monitor the levels of radionuclide exposure in and around its Church Rock uranium mill. This chapter discusses trends and anomalies in the data and compares the measured doses and exposure levels to permissible limits.

High- and low-volume continuous air monitoring results for Unat, Ra-226, and Th-230 for eight Church Rock Mill sites are presented in Appendix B, Figures B-1 through B-8. The eight sites included for the monitoring are as follows:

- Site A - North of the mill site near the NECR trailer park.
- Site B - 1.5 miles northeast of mill in Pipeline Canyon.
- Site B1- The northeast corner of the Kerr-McGee administration building.
- Site C - About 150 feet from the midpoint of the east boundary of the tailings impoundment.
- Site D - Southeast margin of the tailings impoundment on the access road.
- Site E - Near the south end of the tailings impoundment.
- Site F - North of the tailings impoundment at the access road, 1,800 feet east of the intersection with Highway 566.
- Site OCR/IX - Southeast corner of the IX treatment plant.
- Springstead - Near the Springstead Trailer Park sewage treatment plant.

Sampling began in June 1977 at Sites A, B, C, D, and E. Monitoring at the other sites was not initiated until August 1980, and Site B was discontinued. The sampling frequency has been once a month except during mill shutdown between July and October 1979, during which time

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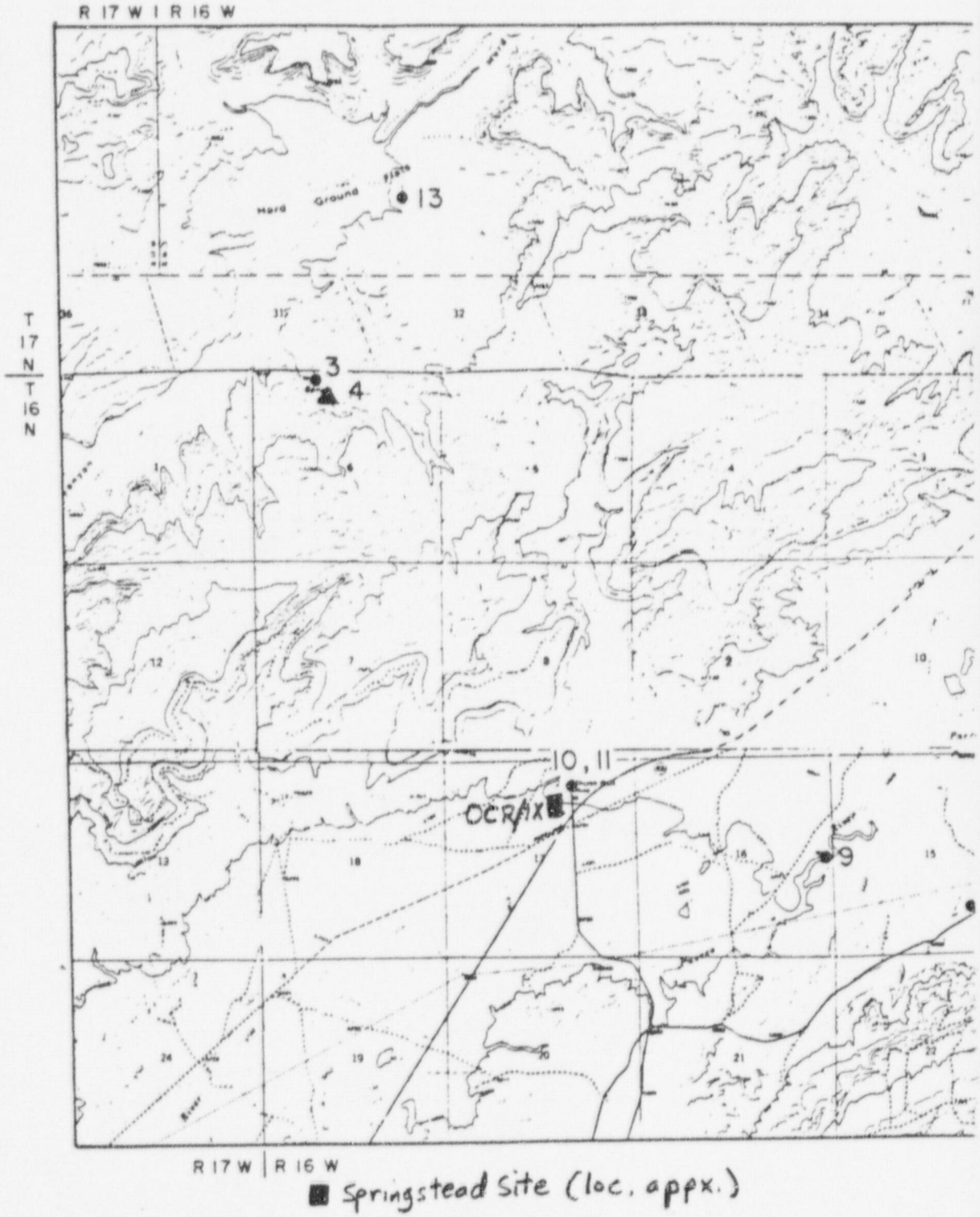
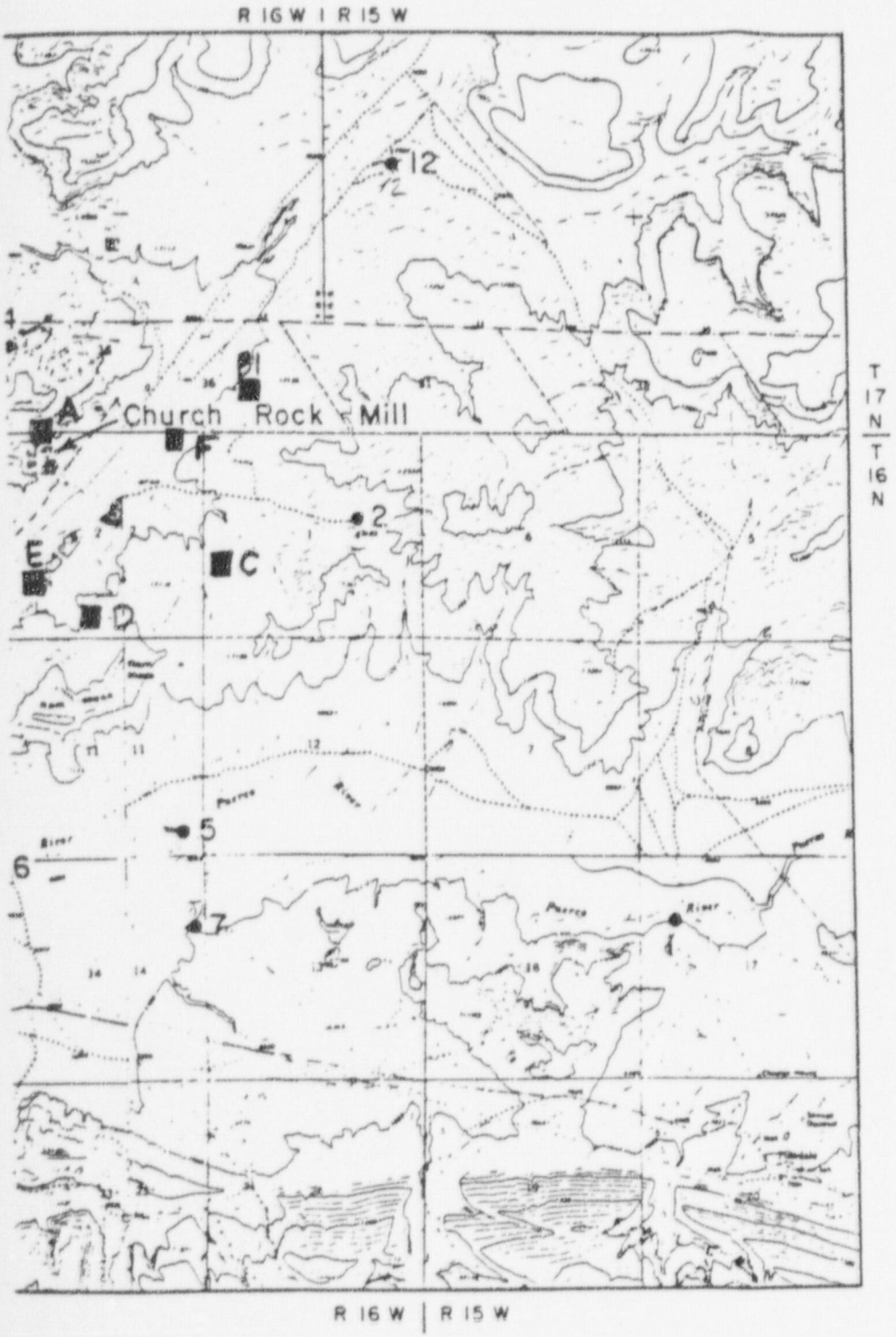
CHECKED BY	WHL 12/21/81
APPROVED BY	KSK 12/21/81
DRAWN BY	EF 11/4/81



REFERENCES: USGS 7.5 MINUTE SERIES QUADRANGLE MAPS PINEDALE, NEW MEXICO (1963); OAK SPRING, NEW MEXICO (1963); HARD GROUND FLATS, NEW MEXICO (1979); CHURCH ROCK, NEW MEXICO (1979)



LEGEND

- ● 6 WELL LOCATION
- ▲ 4 SPRING LOCATION

N

1 0 1 2 KM

1 0 1 MILE

SCALE

NOTE:
SEE TABLE B3.15 FOR WELL AND SPRING CHARACTERISTICS.

A ■ Rd-222 monitoring stations from Fig. C8-1, Table D-3

FIGURE B3-8

EXISTING WELL AND SPRING LOCATIONS

PREPARED FOR

UNC MINING AND MILLING
CHURCH ROCK OPERATIONS

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C4.3 OCCUPATIONAL DOSE

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- Site C - About 150 feet from the midpoint of the east boundary of the tailings impoundment.
- Site D - Southeast margin of the tailings impoundment on the access road.
- Site E - Near the south end of the tailings impoundment.
- Site F - North of the tailings impoundment at the access road, 1,800 feet east of the intersection with Highway 566.
- Site OCR/IX - Southeast corner of the IX treatment plant.
- Springstead - Near the Springstead Trailer Park sewage treatment plant.

Sampling began in June 1977 at Sites A, B, C, D, and E. Monitoring at the other sites was not initiated until August 1980, and Site B was discontinued. The sampling frequency has been once a month except during mill shutdown between July and October 1979, during which time

there was no monitoring. Each of the measured air concentrations is a combination of radionuclides generated by mill operations and naturally occurring radionuclides.

Naturally occurring background concentrations are measured both upwind from the mill and at a reasonable distance from the mill. The combination of both criteria helps to ensure that the measured background concentrations are not influenced by mill operations. Springstead is about six miles southwest from the mill. Being both upwind and distant from the mill, the Springstead values have been accepted by NMEID as background in the area. The net concentrations of each radionuclide can then be calculated by subtracting the background concentrations from the observed concentrations at each monitoring location. The net concentration can then be considered a result of mill operations and compared with the maximum permitted concentration in air of unrestricted areas.

Figures B-1 through B-8 in Appendix B graphically present the measured concentrations in air for each radionuclide at each monitoring site. Appendix B, Tables B.1 through B.3, present the mean concentrations, standard deviations, and number of observations for each radionuclide by year. Net concentrations which result from the subtraction of back-background concentrations from observed values are likewise presented in the tables.

For the purposes of Tables B.1 through B.3, background radiation was taken as:

$7.47 \times 10^{-13} \pm 1.63 \times 10^{-12}$ µci/ml for Unat
$6.04 \times 10^{-15} \pm 1.09 \times 10^{-14}$ µci/ml for Th-230
$3.50 \times 10^{-15} \pm 4.33 \times 10^{-15}$ µci/ml for Ra-226

Appendix B, Tables B.1 through B.3 show that the annual average concentrations for Unat, Th-230, and Ra-226 are within the maximum permissible concentrations (NMEID, 1980, Appendix A) at all sites.

Table D-3

Perimeter Ambient Radon Monitoring[1]
Ambient Radon Activity (pCi/l)

Lucas Chamber

Sample Date	Sample Site 1	2	3
4/25/77-4/27/77	0.80±0.53* (7)	3.14±2.41 (4)	1.16±0.61 (4)
7/28/77	0.24±0.01 (2)	0.12±0.16 (2)	0.35±0.17 (2)
12/2/77	0.12±0.16 (2)	0.23±0.00 (2)	0.12±0.16 (2)
3/19/78	ND**	2.49 (1)	ND
5/24/78	8.76±24.75 (8)	0.17±0.24 (6)	0.19±0.23 (6)
8/18/78	0.06±0.08 (2)	0.03±0.04 (2)	0.10±0.13 (2)
12/26/78	0.99±0.68 (4)	0.33±0.29 (3)	0.38±0.65 (3)
2/23/79	1.09±1.27 (2)	0.2 (1)	ND
6/6/79	0.59 (1)	0 (1)	0.72 (1)
10/23/79	4.20±1.04 (2)	1.52±0.37 (2)	3.39±1.68 (2)

* format of entries: Mean of multiple readings ≥ 0 pCi/l ± 1 standard deviation.
(number of readings ≥ 0 pCi/l)

** ND No Data.

Table D-3 (Cont'd)

Perimeter Ambient Radon Monitoring (cont'd)
Ambient Radon Activity (pCi/l)

Tracketch
(percent error in parentheses)

Sample Period	Sample Site A	B1	C	D	E	F	OCR/LX	Springstead
10/3/80-11/3/80	5.84 (16.6)	2.37 (27.1)	1.61 (33.8)	ND ND	2.37 (27.1)	5.69 (16.8)	2.37 (27.1)	2.67 (25.3)
11/3/80-12/1/80	2.45 (28.1)	2.79 (26.1)	3.96 (21.5)	1.29 (41.2)	1.45 (38.2)	1.45 (38.2)	1.62 (35.8)	1.29 (41.2)
12/1/80-1/8/81	2.67 (22.6)	1.19 (35.8)	2.30 (24.5)	1.19 (35.8)	2.55 (23.2)	2.18 (25.3)	1.32 (33.8)	1.44 (32.0)
1/8/81-2/10/81	2.89 (13.5)	3.26 (12.7)	2.55 (14.5)	2.55 (14.5)	2.84 (13.7)	1.80 (17.7)	ND* ND	1.19 (22.7)
2/10/81-3/11/81	5.11 (10.6)	1.69 (16.0	3.82 (12.5)	2.43 (13.2)	4.15 (10.0)	4.57 (11.3)	3.82 (12.5)	5.11 (10.6)
3/11/81-4/23/81	1.27 (14.7)	1.59 (13.1)	1.35 (14.3)	1.32 (14.4)	1.51 (13.5)	2.33 (10.8)	1.25 (14.9)	1.38 (14.1)
4/23/81-5/15/81	13.54 (7.4)	6.74 (10.6)	7.80 (9.8)	9.85 (8.7)	10.91 (8.2)	11.34 (8.1)	10.77 (8.3)	12.19 (7.8)
5/15/81-6/16/81	2.53 (12.0)	2.03 (13.5)	2.45 (12.2)	4.80 (8.7)	2.67 (11.7)	3.31 (10.5)	5.44 (8.1)	3.16 (10.7)
6/16/81-7/16/81	1.96 (14.4)	1.22 (18.5)	1.22 (18.5)	2.32 (13.2)	3.45 (10.8)	2.04 (14.1)	2.24 (13.5)	2.43 (12.7)

* chip damage.

[1] Sampling began 4/77.
Sampling frequency: monthly (1/81-present); quarterly (4/77-10/79).
Sampling locations: three sites (1977-1979).

1: on fence line off highway on south boundary, west side across from shaft construction, just north of site E.
2: across highway from scale house on tailings fence line.
3: middle of new road on north side of tailings, near site F.

Since 11/80 eight sites are sampled, and 2 additional sites were added in 3/81. All sites coincide with perimeter continuous low volume air monitoring sites:

Site A: north of mill site at NECR Trailer Park.
Site B1: northeast corner of Kerr-McGee Administration Building.
Site C: about 150' east of the midpoint of the east boundary of the tailings impoundment.
Site D: southeast margin of tailings impoundment, on access road.
Site E: near south end of tailings impoundment, about 300' north of Pipeline Arroyo.
Site F: north of tailings impoundment at access road, 1800' east of intersection with NM566.
Site OCR/LX: southwest corner of treatment plant.
Springstead: at sewage treatment plant.

Sampling method: Lucas Chamber (1977-1979); Since 11/80, Tracketch alpha particle detectors, as directed by T. E. Baca (NMEID) to T. F. Bailey (UNC), 7/3/80.