



**COGEMA**

Mining, Inc.

June 15, 2001

**LICENSE SUA-1341  
DOCKET NO. 40-8502**

Mr. Mel Leach, Chief  
Fuel Cycle Licensing Branch, FCSS  
c/o Document Control Desk  
U. S. Nuclear Regulatory Commission  
Washington, D.C. 20555

**RE: Submittal of Additional Information for December, 2000  
Decommissioning Plan, COGEMA Mining, Inc.**

Dear Mr. Leach:

As requested in Mr. Philip Ting's letter dated March 8, 2001, the additional information requested for the December 2000 Decommissioning Plan is summarized in the attached responses.

Changes to the text of the December 2000 Decommissioning Plan were also made in response to NRC's March 8, 2001 letter. Accordingly, replacement pages for the December 2000 Decommissioning Plan are enclosed, along with a guideline page listing which pages are to be replaced. The replacement index pages note those sections of the original plan that have been revised.

Please contact me if you should have any questions regarding the report or decommissioning plan text changes.

Sincerely,

*John Vaselein*  
John Vaselein *by PH*  
Radiation Safety Officer

Enclosures (2 copies)

cc: E. Brummett - NRC, Washington DC  
C. Cain - NRC, Arlington TX  
G. Mooney - WDEQ, Sheridan WY  
K. Baker - ERG, Albuquerque NM  
D. Wichers, W. Heili - COGEMA

**COGEMA, Mining, Inc.**  
**December 2000 Decommissioning Plan**  
**Replacement page guideline for the June 2001 revision**

The attached pages replace the following pages in the original December 2000 Decommissioning Plan.

1. Outside cover pages (inserted on the front and side of the binder).
2. Inside cover page.
3. Table of Contents (pages i through v)
4. Text (pages 1 through 15 and 17 through 78) Save page 16.
5. Appendix A, Tables A-1 and A-2
6. Appendix B
7. Appendix C
8. Appendix E, Procedure D-5

## **COGEMA, Mining, Inc**

### **Additional Information Concerning the December 2000 Decommissioning Plan**

#### **NRC REQUEST # 1**

"Indicate if the 15 areas of elevated soil Ra-226 from spills have been remediated or are designated for future clean-up (see next comment). Also indicate what analytical method is used to determine the U3O8 concentration, and the equivalent uranium (U-nat) activity concentration."

#### Response

A total of 17 spill location areas with soil samples containing >7 pCi/g Radium-226 were listed in Table A-1 and A-2. However, a review of these Tables determined two errors. Irigaray spill # 171 soil analysis was incorrectly listed at 61.7 pCi/g U3O8 and 10.1 pCi/g Radium-226, which were the water analyses. The correct soil analyses are 16.3 pCi/g uranium and 1.2 pCi/g Radium-226. The soil analysis results for uranium were incorrectly listed on both tables as U3O8 instead of as U.

The remaining 16 spill location areas with soil samples containing >7 pCi/g Radium-226 are all wellfield spills, none of which have received final clean-up. Final surveys will be conducted in the spill areas listed in Appendix A, except Irigaray #1, and any soil found to exceed the limits in the approved Decommissioning Plan will be cleaned up.

The analytical method used to determine the uranium concentrations in soil was EPA 908.1 (fluorimetric) up to 1998 and EPA 200.8 (ICP-MS) thereafter. The equivalent uranium activity concentration was calculated in pCi/g, by multiplying mg/kg by 677 (the conversion factor of the specific activity for natural uranium which is 6.77 E-7 /gram). The in-house analytical method used to determine the uranium concentrations in water was Bromo PADAP (colorimetric).

#### Text Changes

Tables A-1 and A-2 from Appendix A were revised to correct the errors.

Section 2.3.1 (Spills) was revised to list the analytical methods used for determination of uranium in soil samples from spills. The revision will also reference that final surveys and possible soil clean-up will be conducted at these spill locations.

#### **NRC REQUEST # 2**

"Provide the estimated area of land (volume or size) that may require remediation. Also, clarify if the sample was obtained before the gamma reading was taken, as stated on page 36."

#### Response

The 2000-2001 Reclamation/Restoration Bond Estimate lists 507 cubic yards (13,700 cubic ft.) of soil which may be contaminated and removed from under the process areas at the Irigaray and Christensen sites. The estimate also lists 1,387 cubic yards (37,449 cubic feet) of the pond leak detection systems (gravel and pipe) which may be contaminated and removed. In addition it is assumed that 12 (5%) of the spill areas listed in Appendix A may have contaminated soil averaging 3 cubic yards, totaling 36 cubic yards.

Each sampling location referenced in Section 3.2.2 was sampled after the gamma readings were taken.

#### Text Changes

Section 3.5 (Estimated Volume of Contaminated Soil) is added to provide an estimate for contaminated soil and pond leak detection systems.

Section 3.2.2 (Gamma Survey and Soil Sample Data Results) was revised to indicate that the gamma readings were taken prior to obtaining soil samples.

### **NRC REQUEST # 3**

“Since some spills have been of pregnant lixiviant, provide a summary of the ranges and average radionuclide concentrations for this type of fluid.”

#### Response

Other than uranium, process water (lixiviant) was not normally analyzed for other radionuclides during mining. However, Ra-226 was analyzed in post-mining/pre-restoration composite samples from all five Mine Units (2,3,4,5&6) at Christensen and from Production Unit 6 at Irigaray. The mean Ra-226 concentration from these samples was 500 pCi/l with a range of 258-1020 pCi/l. Since uranium was the only radionuclide selectively removed from the lixiviant during mining, post-mining/pre-restoration concentrations of all other radionuclides should be near the maximum concentration. Section 3.3 summarizes this data and additional uranium data used to calculate the maximum expected increase in the radionuclide concentrations from spills.

#### Text Changes

Section 3.3 (Process Water Radionuclide Content) was revised to give additional radionuclide concentrations for uranium and Ra-226.

### **NRC REQUEST # 4**

“Indicate if the lab sink drain plumbing includes a septic system that will be surveyed.”

#### Response

The lab sinks at both sites are not connected to the septic systems. These sinks drain into the plants waste sumps, which are pumped into the evaporation ponds.

#### Text Changes

Section 4.2.3 (Laboratories) was revised to indicate that the lab sinks are not connected to the septic systems.

### **NRC REQUEST # 5**

“Section 4.3 should be revised to indicate current regulation of the effluent discharge by the NRC under Part 20.”

#### Response/Text Changes

Section 4.3 (Evaporation Ponds) was revised to state that COGEMA would also follow the NRC’s criteria for liquid effluents released to unrestricted areas.

### **NRC REQUEST # 6**

Indicate which background data were obtained from the surface 15 cm of soil and an area of 100m<sup>2</sup> or any additional reasons why the sample depth intervals are adequate. Also, indicate which data were subjected to adequate quality control and assurance measure. In addition, indicate if all these sample locations are geologically and chemically similar to the contaminated areas.”

#### Response

We remain convinced that the data are adequate to determine baseline radionuclide concentrations. We also believe a new sampling program (post-operations) would not have higher credibility. Our responses to these 3 requests as reflected in the changes made to the text are:

##### *a.) Why the background sampling methods are adequate.*

We agree that none of the samples were taken from the top 15-cm layer and none were composites from a 100-m<sup>2</sup> area. Most of the samples were taken from the top 5-cm layer and were single point samples. Other samples were taken from the top 30-cm layer or from deeper layers. For Christensen Ranch, the very extensive procedures in NRC Reg. Guide 4.14 were followed and reflect NRC’s best guidance on pre-operational monitoring. A review of MARSSIM guidance failed to link the sampling method of the reference area to the verification method. Since few sites have adequate pre-operations data, MARSSIM addresses the use of a reference area, recognizing the potential error in choosing a truly representative

reference area.

We believe that baseline studies should be adequate to describe the mean background levels of the constituents of concern and the natural spatial variation. Ideally, baseline studies use only pre-operational data and samples from the potentially affected area. Unless it can be demonstrated that excessive spatial variation exists, the results should be independent of sampling method.

As indicated in the NRC's comments, the Christensen Ranch study showed no statistically significant variation of Ra-226 concentration down to a depth of 100 cm at the six sampling points. At the one point where the samples were analyzed for Th-230, the reported concentrations in the samples varied with depth from 0.8 to 5 pCi/g. While one point is probably not sufficient to draw a conclusion, we do not consider this important since Th-230 is not a constituent of concern at the site since the process water does not show evidence of elevated Th-230.

b.) Why the quality control measures are adequate.

The variation in baseline concentrations arises from real spatial variation and variation in analytical results. For most sites, the variation in the analytical results is normally a major portion of the total variation. The magnitude of the variation is evident from inter-laboratory comparison studies and analyses of duplicate samples. We believe that the variations in reported results, in most cases, arise primarily from small laboratory biases and statistical analytical errors. In a few cases in this report, arguments were made to discard data when the values appeared unreasonable.

Naturally, the twenty-year old pre-operations data for Irigaray Project may not conform to current quality documentation practices. However, analytical methods have not changed. The extensive pre-operations characterization of Christensen Ranch, however, was designed and implemented in full compliance with Reg. Guide 4.14, including the quality requirements. In addition, the environmental monitoring data were obtained from the NRC-approved and NRC-audited environmental monitoring program.

c.) *Similarity of sample locations to contaminated areas.*

As indicated above, the Christensen Ranch study was truly a pre-operations study in the potentially affected area, following NRC guidance. The earlier pre-operations data from Irigaray was obtained from samples taken at the environmental monitoring stations at the site. We believe that this data set is more than sufficient to characterize the sites.

In order to increase the size of our database, the post-operations data were also evaluated (assessed by mean and standard deviation at sampling points over time) and determined to be very similar to the pre-operations data. This is not surprising since the ISL process is relatively emissions free. These data sets were used to support the proposed mean background concentrations for the site.

In order to assess the variation of the constituents, an argument has been made in the text to support the conclusion that there is no reason to consider the two sites geochemically or geologically different. There is also no evidence that the geochemistry variation within a site is above normal since there is no evidence of large soil type variations or significant mineralized surface outcrops.

#### Text Changes

Section 2.4 (Natural Background Radionuclides in Soil), which includes Sections 2.4.1 through 2.4.5, was revised to provide additional information related to these three concerns.

#### **NRC REQUEST # 7**

"Justify the proposed method of surveying pipes as adequate to demonstrate release criteria have been met. Indicate how COGEMA will determine if a trap or access point is representative of the entire pipe and what is the typical distance between such points."

### Response

The general method of surveying the interior surfaces of pipes given in Section 5.1 (page 44), was taken from Section 4.C. of Regulatory Guide 1.86. The same language is also found in the NRC guidance document entitled, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated May 1987. COGEMA is required to follow this guideline as per License Section 9.8 and believes that it is an adequate method for determining if release criteria are met.

The contamination on interior surfaces of piping and ducts will be determined by surveying at both ends and at all traps and other appropriate access points, provided that contamination at these locations is likely to be representative. Based on limited past experience, interior pipe contamination was found to be uniform with no evidence of buildup at connections, valves or other such or access points. Most wellfield pipe is poly-plastic which averages 300 feet in length with only end connections. Plant piping is mostly iron and PVC plastic which has connections spaced at 20 feet or less.

### Text Changes

Section 5.1 (Equipment and Materials to be Released for Unrestricted Use) was revised to provide the information in the response concerning pipe contamination and surveys.

### **NRC REQUEST # 8**

"Indicate if an administrative limit or ALARA goal has been chosen for subsurface Ra-226 and for the uranium concentrations and if the proposed uranium limits consider the chemical toxicity. Also, estimate what subsurface areas (location and depth) might be under consideration for application of the subsurface criterion beside pipe trenches."

### Response

The ALARA subsurface goals are two-thirds of the proposed limits of 15 pCi/g above background for Ra-226 and 600 pCi/g for uranium. Therefore, the proposed ALARA subsurface goals are 10 pCi/g above background for Ra-226 and 400 pCi/g for uranium.

A proposed ALARA surface goal for uranium is 150 pCi/g, averaged over an area of 100 m<sup>2</sup>. No ALARA goal is proposed for surface Ra-226, because it is felt that cleanup procedures will result in near background Ra-226 concentrations.

A chemical toxicity assessment was completed which determined that that intakes at the proposed limits would not result in toxicity effects.

Besides pipe trenches, subsurface contamination will more than likely be found beneath the process portion of the Irigaray Plant and possibly beneath evaporation pond liners. Note that the worksheets in the surety bond uses an average of 3 inches (depth) for removal in these areas.

### Text Changes

Section 7.1 (Cleanup Limits for Soils) was revised to include the proposed ALARA goals and how they were determined, the uranium toxicity calculations in comparison to the proposed limits, and to list other areas where subsurface contamination will likely be found. Section 7.2.3 (Excavation Control Monitoring) was also revised to include this information where applicable.

### **NRC REQUEST # 9**

"Indicate how only alpha measurements will be adequate to characterize the surface activity of buildings and structures, given the uneven surface of some of the contaminated material. Indicate if alpha and beta measurement comparisons have been done."

### Response

Beta measurements may be required to adequately characterize some building surfaces. Therefore we

have proposed making three beta measurements per each 100-m<sup>2</sup> area to provide a measure of possible alpha emission rate attenuation.

We have evaluated the available portable instrumentation for conducting beta surveys. Because of the higher background count rate for beta detectors, we naturally find them to have a much higher MDC than alpha detectors. This assumes, of course, that the alpha emission rate is not attenuated by surface coatings, etc. This supports the argument for using alpha measurements as the primary tool for demonstrating compliance with the cleanup limits with beta measurements as additional assurance that the alpha emission rates have not been attenuated.

On a related issue concerning surface activity on buildings and structures, we took this opportunity to update Appendix B by using the latest version of RESRAD-Build, the NRC code for assessing the dose from contaminated buildings.

#### Text Changes

Section 5.2 (Buildings to be Released for Unrestricted Use) was revised to reference Appendix C (Building Contamination Survey and Sampling Plan). Appendix C was revised to include a requirement that surfaces be monitored for beta emissions at a minimum of 3 measurements for each 100-m<sup>2</sup> survey unit and to discuss beta and alpha survey comparisons. Appendix B (Dose Assessment-Surface Contamination) was revised to use the updated RESRAD-Build code.

#### **NRC REQUEST # 10**

"Indicate if the same sample locations in Table 3-1 are the same for ERG and COGEMA measurements. Also, indicate which procedure ERG's or COGEMA's will be used for the final status survey (Appendix C) and why that procedure is adequate, e.g. adequate sensitivity."

#### Response

The ERG and COGEMA measurements listed in Table 3-1 were made at different times and locations. All measurements were made using similar ZnS alpha detectors. The purpose of the measurements was to measure current plant surface contamination and its variability. As indicated in the Appendix C, gas-filled proportional detectors will be used during decommissioning due to their increased efficiency and sensitivity. Appendix C outlines the procedure for the final status survey.

#### Text Changes

Section 3.1.1 (Method and Equipment) and Section 3.1.2 (Results) were revised to clarify how the survey data was obtained in revised Table 3-1.

#### **NRC REQUEST # 11**

Indicate the ALARA effort /limit that will apply to the uranium chain value."

#### Response

Currently, an ALARA goal of 1,000 dpm/100 cm<sup>2</sup> of total alpha is used where practical, which also simplifies surveys and can eliminate the need for removable surveys. This ALARA goal will continue during decommissioning. However, the limits given in Section 5.1 for removable, average and maximum alpha may still be used if a reasonable effort has been made to eliminate residual contamination as stated in Section 5.1.

#### Text Changes

Section 5.1 (Equipment and Materials to be Released for Unrestricted Use) was revised to state a ALARA contamination goal of 1,000 dpm/100 cm<sup>2</sup> for total alpha.

#### **NRC REQUEST # 12**

Indicate why flushing is assumed to be as successful as soaking the pipe. Also, indicate how much pipe (linear feet or miles) might be decontaminated in this manner."

### Response

Pipe flushing should be even more effective than soaking to remove interior contamination since more water movement and turbulence is created. If COGEMA decides to decontaminate interior piping with hydrochloric acid solutions, experiments will first be conducted to determine the most efficient and safest method. Waste solution will be placed in the evaporation ponds and ultimately be injected into a Class I injection well. Worksheet 6 of the updated bond lists a total of 694,700 linear feet of wellfield piping averaging 3 inches in outside diameter. This would be the amount most likely to be decontaminated by flushing .

### Text Changes

Section 3.4 (Studies to Reduce the Contamination Levels in Buried Pipes) was revised to provide additional information concerning pipe decontamination and the estimated linear feet involved.

### **NRC REQUEST # 13**

“Indicate why it is assumed that 7 gamma records per grid with GPS survey will provide reliable data and be comparable to the other method proposed.”

### Response

The selection of the minimum number of data records necessary for calculating an average gamma count rate over a 100 m<sup>2</sup> grid block depends on the characteristic size of the contaminated area and the spacing of the data records. The seven records were proposed based on prior experience at similar sites where a minimum of five to seven records were required. It should be noted that to assure a minimum of seven records per grid block, the survey method is normally designed to produce an average of more than 12 records per grid block. In addition, the procedures are designed to assure that the records are uniformly distributed over the grid block. Within the procedures, the data maps are reviewed manually for missing data and an explanation made as to why it was not possible to obtain the data.

We have rewritten Section 7.2 to include a description of the total process of assuring that the areas meet the cleanup criteria. It will then be evident to the reviewer that by the time the final verification gamma surveys are done, the area will exhibit uniformly low gamma values and that the data density will be rather uniform. Lastly, the sampling method is a biased method since ten percent of the grid blocks with the highest average gamma levels are sampled. If any of those fail, the next ten percent will be sampled, and so on. This method either provides assurance that the proposed gamma action level was appropriately chosen or provides an indication of what the proper action level should have been.

In the final survey, a minimum of seven data points is proposed to assure that there are no 100-m<sup>2</sup> grid blocks with data missing from significant portions of the grid blocks. The identification of the grid blocks and the counting of data records are done by computer, as described in SOP D-3. Since contaminated areas will have already been remediated to assure all points are below the action level, the final gamma data should be uniformly low and near background levels. The only alternative to reducing grid blocks to below the gamma action level is to verify that the grid block meets the cleanup criteria by soil sampling and analysis.

The sampling program detailed in SOP D-3 provides an added level of assurance that the gamma action level conservatively predicts that an area meets the cleanup criteria. The average count rate for the 100-m<sup>2</sup> grid blocks within the two areas of each site is calculated. The grid blocks are ranked according to the average count rate and the top ten percent of the grid blocks are sampled according to the procedure. If any of these grid blocks fail verification by soil sampling and analysis, the second ten percent of the grid blocks are sampled, and so on.

### Text Changes

Section 7.2 (Soil Cleanup and Verification) was revised to include additional information on the process of assuring that the areas meet the cleanup criteria.

#### **NRC REQUEST # 14**

“Justify that these changes (reductions) in monitoring are protective considering that dryer operation will take place 2-3 weeks /yr and plant decommissioning will be performed.”

#### Response

Annual beta surveys were eliminated because of historically low exposures compared to the dose limits. Past beta surveys were conducted only for information purposes. The highest beta exposure during year 2000 was 2.2 mrem/hour in the drypack furnace room, however, employee exposure time in the drypack furnace room continues to decrease as less yellowcake is dried during the restoration process. The maximum annual employee exposure in the drypack furnace rooms during restoration, is estimated at only 16 hours. Excluding the furnace rooms, none of the other beta exposure surveys exceeded 0.31 mrem/hour, which are minimal compared to the annual shallow-dose limits of 15 rems for the eye lens and 50 mrem to any other extremity.

Although daily ventilation inspections were eliminated, they are included as part of the weekly in-plant inspections, which are required in Section 11.5 of the newly amended license. Weekly inspections are considered adequate because none of the ventilation systems, other than the dryer scrubber system, are needed to maintain airborne radionuclides below the action level (25% of DAC). Note that the dryer scrubber system is monitored continuously during operation. As amended in License Section 11.5, daily walk-through inspections of the Irigaray facility will be conducted during operation of the yellowcake dryer, to determine that radiation control practices are being implemented appropriately.

Surface contamination swipe frequency was changed from weekly to monthly because of historically low surface activity levels which have not exceeded the NRC limit (1,000 dpm/100cm<sup>2</sup>) and rarely exceeded the internal action level of 100 dpm/100cm<sup>2</sup>.

#### Text Changes

Section 8.6 (Health Physics Surveys and Dose Calculations) was revised to justify the reduction in monitoring. Table 8-1 (Radiological Exposure and Contamination Monitoring Summary) was revised to list the daily and weekly inspection requirements, as per License Section 11.5.

#### **NRC REQUEST # 15**

“Appendix E, procedure D-5, page 2 should indicate that the walls of deep excavations will be scanned if contamination could extend laterally.”

#### Response

The procedure was revised to include sidewall surveys for areas of deep excavation.

#### Text Changes

Procedure D-5 (Soil Cleanup Verification Survey) in Appendix E was revised to include sidewall surveys for areas of deep excavation.

#### **NRC REQUEST # 16**

“Provide or describe the QA/QC program for field data acquisition e.g., gamma measurements.”

#### Response

The steps taken to assure quality field measurements are integrated into the SOPs for conducting surveys and maintaining equipment. These steps have been summarized and placed in a new section of the text.

#### Text Changes

Section 7.2.6 (Field Measurements Quality Control) was added to list the quality control steps taken during field measurements.

### NRC REQUEST # 17

"Indicate what line item in the August submittal contains the estimated cost for the radiological monitoring and measurements that will be needed for soil and building cleanup, verification, and for building and equipment dismantlement. Also, itemize these costs (e.g., technician and RSO time, soil analysis, report preparation) that would be incurred if a third party had to perform the decommissioning according to the proposed plan."

#### Response

As stated in Section 11.0 of the decommissioning plan, the entire reclamation surety estimate is based on the premise that a third party contractor is hired to perform the reclamation. Each worksheet of the surety estimate has been developed using unit rates that include labor, materials, etc., similar to typical construction cost estimating guides. In addition, the surety estimate also includes a 21.5% contingency that provides for the following third party costs:

Project Design	2%	\$ 202,929
Contractor Profit & Mobilization	8%	\$ 811,717
Pre-construction Investigation	1%	\$ 101,465
Project Management	3%	\$ 304,394
On-site Monitoring	0.5%	\$ 50,732
Site Security & Liability Assurance	1%	\$ 101,465
Longterm Administration	2%	\$ 202,929
Unknowns	4%	<u>\$ 405,859</u>
TOTALS	21.5%	\$2,181,490
Inflation Factor (1994-2000)	15.6%	<u>\$ 340,312</u>
		\$2,521,802

The cost for radiological monitoring and measurements that will be needed for soil and building cleanup and verification were assumed to be a part of the labor conducting the dismantlement of whatever structure is in question. This type of supportive information was provided in the 1994 surety estimate that forms the basis of this surety estimate (has been updated annually, and costs inflated, since then). For example, the General Information states "All radiation surveys are conducted by the labor crew foreman, who is trained to conduct such surveys". Two examples from Worksheet 2 (Plant Equipment Removal and Disposal) are provided as follows:

Decontamination unit rate of \$462/load:

#### Assumptions:

- 2 cubic foot = 6 square feet (surface)
- 2 laborers can powerwash or sandblast 10 square feet per minute, or 1.7 cubic feet per minute = 102 cubic feet/hour
- 1 load = 540 cubic feet

#### Labor:

- 2 laborers @ \$15/hour = \$30/hour
- 540 cubic feet/load divided by 102 cubic feet /hour = 5.29 hours/load
- 5.29 hours/load x \$30/hour = \$158.70

#### Equipment Rental:

- 2 pressure washers @ \$7/hour
- 1 30 HP air compressor @ \$5/hour
- 2 sandblast pots @ \$5/hour  
= \$29/hour
- 5.29 hours x \$29/hour = \$153.40

#### Materials:

- Sand: 75 cubic feet @ \$1/foot = \$75
- 10% HCL, 440 gallons @ \$0.17/gal = \$75  
\$150

TOTAL = \$158.70 + \$153.40 + \$150 = \$462.00 per load (inflated to 2000\$ = \$534/load)

Dismantling and Loading cost of \$600/load:

Labor Crew:	1 foreman	@\$20/hour
	4 laborers	@\$15/hour each
	1 truck	@\$10/hour
	1 welder	@\$35/hour
		\$125/hour
	Estimate:	4 hours @ \$125/hour = \$500
	Equipment Rental:	1 front-end loader with operator @ \$50/hour
	Estimate:	2 hours @ \$50/hour = \$100
	TOTAL =	\$600/load (inflated to 2000\$ = \$694/load)

Additionally, applicable worksheets provide an estimate of the percentage of equipment, concrete or soils that require removal, decontamination and shipment to a licensed facility (PMC Shirley Basin tailings impoundment). Worksheet 6 of the surety estimate provides the costs for removal, volume reduction, loading and handling, shipping and disposal charges for ALL wellfield piping, although the decommissioning plan states that buried piping will remain in place if surveys show that applicable limits are met. The decontamination costs for this piping of \$462/load do not apply as it is calculated to be shipped to Shirley Basin for disposal. The decontamination and survey charges will be far less than the costs associated with the removal, volume reduction, shipping and disposal of this piping at Shirley Basin.

As far as a line item for RSO time and report preparation, this has always been assumed to be part of the third party management, included in the Project Management contingency (3%, \$304,394). Soil analysis is included on Worksheet 7. A radiation survey cost of \$75/acre (\$87/acre in year 2000\$) is the estimate used for the sample preparation and analysis of two soil samples per acre plus labor for a surface gamma survey on a grid basis. We now realize that this is an insufficient cost based on our decommissioning plan. The current estimate for this is:

Soil Sampling and Analysis Cost

- \$75/soil sample for digestion, U and Ra-226 analysis
- \$25/soil sample for labor
- Total = \$100/sample, and an average of 4 samples per acre = \$400/acre

Gamma Characterization and Verification Survey

- \$100/acre for GPS survey
- \$50/acre for grid establishment
- \$30/acre for verification after excavation
- Total = \$180/acre

Grand Total = \$580/acre

It is proposed that the above increases for the soil sampling/gamma survey be incorporated into Worksheet 7 of the surety estimate to replace the current \$75/acre estimate. Additionally, RSO and administrative time can be added as a line item if NRC would prefer. If NRC agrees with this, the surety estimate due in August, 2001 will be revised to reflect these changes.

#### Text Changes

No changes have been made to the text for this response.

#### **NRC REQUEST # 18**

"Indicate where in the decommissioning plan the non-radiological hazardous constituents of byproduct material are addressed in compliance with Criterion 6(7).

#### Response

The potential impacts from non-radiological components of byproduct material disposed of during ISL operations should be minimal, as are the radiological impacts. One non-radiological constituent that could be of interest from spilled lixiviant in the wellfields is selenium. The analytical results from the end-of-mining recovery composite samples from all wellfields at Christensen and Production Unit 6 at Irigaray show an average of 2.8 mg/l of selenium. To understand the impact of this amount of selenium on the local soils, one

must know the background selenium concentration in the soils. Background selenium concentrations in the local soils were not established prior to the mining activity, but are generally known to be high in the surface soils. Assuming that the local grasses and plants are already adapted to higher selenium concentrations in soils, the small amount of spilled solution should not have significantly affected the local soils or plants. It is also probable that the cleanup of any radiologically contaminated soil will also remove any abnormal selenium concentrations, if they exist.

#### Text Changes

Section 9.8 (Non-radiological Impacts) was added to discuss the potential impacts from non-radiological components of byproduct material and provide detailed information concerning selenium.

#### **NRC REQUEST # 19**

“Justify the various proposed changes reflected in Table 9-1.”

#### Response

The environmental radiological monitoring reductions and eliminations were based on many years of data collection, which showed no concerning trends. During restoration and decommissioning, it is expected that environmental radiological effluents will be no greater than in the past. Emissions from the yellowcake dryer stack will actually decrease since it will operate for only 2-3 weeks per year. A summary of the environmental radiological monitoring programs that are proposed for elimination or reduced sampling, are listed below.

Quarterly ranch well (regional groundwater) sampling was reduced to annual.

Annual sampling of surface water location IR-5 was eliminated because it is located on the Powder River approximately 4 miles from the Irigaray Site. Since surface discharge waters enter Willow Creek, it is more appropriate to continue sampling Willow Creek instead of Powder River. Willow Creek is an intermittent stream and flow samples are not always available. Quarterly surface water sampling of Willow Creek was reduced to annual and will be conducted when there is an adequate flow.

Continuous radon and gamma monitoring was eliminated.

Annual soil and vegetation sampling was eliminated.

Semi-annual sampling of the yellowcake dryer stack was eliminated, however, continuous sampling of airborne radionuclides from 5 surrounding locations will continue when the dryer is operating.

#### Text Changes

Sections 9.4 (Surface Water), 9.6 (Groundwater) and 9.7 (Environmental Radiological Monitoring) were revised to justify the monitoring changes.

#### **NRC REQUEST # 20**

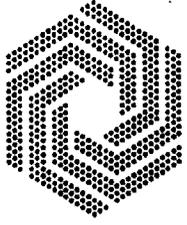
To assist the staff in preparation of an environmental assessment for this license amendment, indicate the date of the latest environmental report, wildlife survey, and cultural resources survey. Also, summarize the results of any of these reports if a copy has not been submitted to the NRC.”

#### Response

Donna Wichers provided this information to Elaine Brummett by E-mail in April 2001.

#### Text Changes

None required.



**COGEMA**

**Mining, Inc.**

**DECOMMISSIONING PLAN**

**FOR**

**IRIGARAY AND CHRISTENSEN RANCH  
PROJECTS**

**NRC Source Materials License SUA-1341**

**and**

**WDEQ PERMIT TO MINE No, 478, A-2**

**December 2000**

**Revised June 2001**

**Decommissioning Plan  
for  
Irigaray and Christensen Ranch Projects  
COGEMA Mining, Inc.**

**NRC Source Material License SUA-1341  
Docket No. 40-8502  
and  
WDEQ Permit to Mine No. 478, A-2**

**December 2000  
Revised June 2001**

**Prepared for:  
COGEMA Mining, Inc.  
935 Pendell Avenue  
P. O. Box 730  
Mills, Wyoming 82644**

**Prepared by:  
Environmental Restoration Group, Inc.  
12809 Arroyo de Vista NE  
Albuquerque, NM 87111**

# Table of Contents

# Page

1.0 Introduction	1
2.0 Site Description	2
2.1 Facilities	2
2.2 Site History	3
2.3 Known Contamination Events	4
2.3.1 Spills *	4
2.3.2 Pond Liner Leaks	6
2.4 Natural Background Radionuclides in Soil *	7
2.4.1 Irigaray Pre-Operations Background Sample Results *	9
2.4.2 Christensen Project Pre-Operations Background Sample Results *	10
2.4.3 Irigaray Project Post-Operations Sample Results *	20
2.4.4 Christensen Ranch Post-Operations Background Sample Results *	25
2.4.5 Discussion and Conclusion *	25
3.0 Current Site Conditions	31
3.1 Building Surface Contamination Survey and Exposure Rate Measurements	31
3.1.1 Method and Equipment *	31
3.1.2 Results *	32
3.2 Gamma Surveys and Soil Sampling	34
3.2.1 GPS and Radiological Equipment	34
3.2.2 Gamma Survey and Soil Sample Data Results *	34
3.3 Process Water Radionuclide Content *	39
3.4 Studies to Reduce the Contamination Levels in Buried Pipes *	40
3.5 Estimated Volume of Contaminated Soil *	41
4.0 Decommissioning	42
4.1 Wellfields	42
4.1.1 Well Plugging and Abandonment	42

4.1.2 Trunk Lines, Pipes and Wellfield Equipment	43
4.2 Facilities	44
4.2.1 Process Plants	44
4.2.2 Wellfield Buildings	44
4.2.3 Laboratories *	45
4.3 Evaporation Ponds*	45
5.0 Disposal Options and Release Surveys	46
5.1 Equipment and Materials to be Released for Unrestricted Use *	46
5.2 Buildings to be Released for Unrestricted Use *	48
5.3 Contaminated Equipment, Materials, and Buildings to be Transferred to Another Licensee	49
5.4 Contaminated Equipment, Materials, and Buildings to be Disposed of as Byproduct Material	49
6.0 Derived Decontamination Limits and Verification Plan for Buildings	51
6.1 Derived Decontamination Limits for Facilities	51
6.2 Characterization and Verification Plan for Buildings	51
7.0 Cleanup of Surface and Subsurface Soils	53
7.1 Cleanup Limits for Soils *	53
7.2 Soil and Cleanup Verification *	59
7.2.1 Gamma Action Level	61
7.2.2 Gamma-Ray Surveys for Characterization and Verification	67
7.2.3 Excavation Control Monitoring *	70
7.2.4 Soil Cleanup Verification Survey and Sampling Plan	71
7.2.5 Laboratory Quality Assurance	71
7.2.6 Field Measurements Quality Control *	72
8.0 Radiation Safety Program	74

\* These sections have been modified compared to the December 2000 version

8.1 D&D Task Analysis	74
8.2 Personnel Training	75
8.3 Standard Operating Procedures (SOPs)	75
8.4 Respiratory Protection Program	76
8.5 Radiation Work Permit (RWP) Program	76
8.6 Health Physics Surveys and Dose Calculations *	76
8.7 Shipments of Radioactive Materials	78
8.8 Records and Reports	79
9.0 Environmental Impacts	80
9.1 Land Use	80
9.2 Air Quality	80
9.3 Wildlife	80
9.4 Surface Water *	81
9.5 Archaeological Sites	81
9.6 Groundwater *	81
9.7 Environmental Radiological Monitoring *	83
9.8 Non-Radiological Impacts*	83
10.0 Post-Decommissioning Reclamation Procedures	85
11.0 Decommissioning Schedule and Cost Estimate	86
12.0 Final Decommissioning Completion Report	89
13.0 References	90

<b>List of Figures</b>	<b>Page</b>
Figure 2-1 Pre and Post-Operational Soil Sample Locations at the Irigaray Project	13
Figure 2-2 Irigaray Project Production Units 1-9	14
Figure 2-3 Pre-Mining Radiological Assessment Gamma Survey and Surfaced Soil Sample Location Map	16
Figure 3-1 Gamma Survey and Soil Sample Locations at Christensen Ranch Site	35
Figure 3-2 Gamma Survey and Soil Sample Locations at Irigaray Site	36
Figure 7-1 Gamma Count Rate as a Function of Various Radionuclide Concentrations in Soil	64
Figure 7-2 Gamma Count Rate as a Function of Ra-226 Concentration in Soil	65
Figure 7-3 Gamma Count Rate as a Function of Uranium Concentration in Soil	66
Figure 7-4 Relationship between Ludlum Model 19 and Ludlum Model 44-10 Readings	68
Figure 11-1 Preliminary Schedule of Decommissioning and Reclamation of Irigaray and Christensen Ranch Project	87

### **List of Tables**

Table 2-1 Proposed Background Concentrations	9
Table 2-2 Pre-Operational Soil Sample Results for Irigaray Project	11
Table 2-3 Pre-Operational Soil Sample Results for Ore Transects, Four Directions, and Air Sampling Stations at Christensen Ranch Project	17
Table 2-4 Pre-Operational Soil Sample Results taken at depth at Christensen Ranch Project Air Sampling Stations	19
Table 2-5 Post-Operational Soil Sample Results at Irigaray Project	21
Table 2-6 Post-Operational Soil Sample Results at Christensen Ranch Project	26
Table 2-7 Summary of Soil Sample Results	28
Table 3-1 Total Alpha Surface Contamination in Plant Buildings *	33
Table 3-2 Gamma Count Rate , Exposure Rate, and Radionuclide Concentrations at Soil Sampling Locations	38
Table 3-3 Aquifer Restoration Water Radionuclide Content at Christensen Ranch Project	39

\* These sections have been modified compared to the December 2000 version

Table 7-1 Annual Intake of Uranium from Ingestion	57
Table 8-1 Radiological Exposure and Contamination Monitoring Summary Irigaray and Christensen Ranch Projects *	77
Table 9-1 Environmental Radiological Monitoring Summary Irigaray and Christensen Ranch Projects	82

\* These tables have been modified or added compared to the December 2000 version

### **List of Appendices and Attachments**

- A. Spills \*
- B. Dose Assessment-Surface Contamination
- C. Building Contamination Survey and Sampling Plan\*
- D. Derivation of Soil Cleanup Criteria
- E. Procedures\*

Attachment 1 Plant Drawing and Map for Irigaray Project

Attachment 2 Plant Drawing and Map for Christensen Ranch Project

# **Irigaray and Christensen Ranch Projects**

## **Decommissioning Plan**

### **1.0 Introduction**

COGEMA Mining, Inc. (COGEMA) submitted a decommissioning plan (COGEMA, 2000) on May 8, 2000, for its Christensen Ranch and Irigaray Projects as required in Amendment 3 and Section 12.5 of License SUA-1341. By letter dated July 3, 2000, the NRC staff identified omissions or deficiencies in that plan. After discussions with staff of the U. S. Nuclear Regulatory Commission (NRC), COGEMA is replacing the previously submitted plan with this plan to address the omissions and deficiencies.

Since COGEMA has ceased production at both its Christensen Ranch and Irigaray Projects, groundwater restoration is now the main operational activity at these sites. It is estimated that groundwater restoration will be completed in 2005; therefore, much of the process facilities and wellfields will continue to be used until that time. Once groundwater restoration is completed and final approval is received by both the Wyoming Department of Environmental Quality (WDEQ) and the NRC, COGEMA will complete decommissioning as discussed in Sections 4.0 and 5.0 of this plan.

After removal and disposition of the facilities, including the cleanup of any contaminated soil, the surface will then be reclaimed according to the Wyoming Department of Environmental Quality and NRC-approved license renewal application submitted on January 5, 1996 (Section 6.3, Surface Reclamation).

## **2.0 Site Description**

The Irigaray Project and the Christensen Ranch Project are both uranium in situ leach facilities, located approximately 7 miles apart (13 road miles). The projects are similar in nature and are integral to each other. Although both projects extracted uranium from underground aquifers, only the Irigaray Project has uranium recovery and packaging facilities. The loaded ion exchange resin from the Christensen Ranch Project is transferred to the Irigaray Project for uranium recovery and packaging.

### **2.1 Facilities**

Both sites generally consist of uranium extraction/groundwater restoration plants, wellfields, and evaporation ponds. The uranium extraction portion of the plants contain sand filter tanks for filtering unwanted solids from the wellfield groundwater, and ion exchange resin columns for removing the dissolved uranium from the filtered wellfield groundwater. The groundwater restoration facilities portion of the plants contains reverse osmosis filtration units for removing dissolved solids from the wellfield groundwater. In addition, the plants contain chemical storage tanks for uranium extraction and/or restoration purposes, and various pumps and piping.

The wellfields contain injection and recovery wells completed in the ore zone at depths down to 600 feet. Pipes from the injection and recovery wells are completed to the plants through connecting wellfield buildings and trunk lines. The wellfields also contain monitoring wells for sampling the groundwater around the perimeter of the mined ore zone and in the aquifers above and below it.

All ponds, except the permeate storage pond at the Christensen Ranch Project, have a synthetic liner placed over leak detection piping. The permeate storage pond is unlined because it is used to store low-TDS permeate from the reverse osmosis filtration process, which meets NPDES water quality standards for surface discharge. Site-specific details for each project are given below.

The Irigaray Project is located in Johnson County, approximately 90 miles NNE of Casper, Wyoming. The Irigaray Project portion of the WDEQ Permit No. 478 boundary encompasses 671 acres. The total acreage disturbed by the Irigaray operations is approximately 133 acres. This

estimate includes the plant with a dryer, a wellfield building, topsoil piles, eleven lined evaporation ponds, roads and wellfields, several small utility buildings, and the peripheral disturbance. See the plant layout and general location and spill maps within Attachment 1 for a layout of the facilities and wellfields. The uranium recovery and packaging facilities are located in the plant and consist of an elution circuit for the ion exchange resin, a uranium precipitation circuit, a yellowcake filtering (dewatering) circuit, yellowcake storage tanks, and a yellowcake dryer and packing circuit.

The Christensen Ranch Project is located about 13 road miles SE of the Irigaray Project. It is located in both Johnson and Campbell Counties, Wyoming. The permitted area is an irregular shaped but continuous land unit encompassing 14,035 acres. The total acreage disturbed by the Christensen Ranch Project operations is approximately 554 acres. This includes the satellite plant, four evaporation ponds, one permeate storage pond, two shop buildings, roads and wellfields, topsoil piles, numerous small utility buildings, two disposal wells, and the peripheral disturbance. See the plant layout and general location and spill maps within Attachment 2 for a layout of the facilities and wellfields.

## **2.2 Site History**

The Irigaray Project began commercial operation in 1978 and was then owned and operated by Wyoming Mineral Corporation a subsidiary of Westinghouse Electric Corporation. In 1982, operations ceased and the facility was placed on standby status pending improvements in the uranium market. In 1987, Malapai Resources Company, a subsidiary of Arizona Public Service, purchased the Irigaray Project and resumed operations. In 1988 Malapai amended the WDEQ Permit 478 and NRC License SUA-1341 to include the Christensen Ranch Project and began commercial operations there in 1989. In 1990 the site was sold to Electricite de France, the French Nuclear utility, with Total Minerals Corporation as the operator. In 1993, COGEMA acquired the assets of Total Minerals Corporation and changed the name of the operating entity to COGEMA Mining, Inc. COGEMA ended mining at the Irigaray Project in 1994, and Christensen Ranch Project production increased until it peaked in 1996 at 746,478 lbs. uranium (as U3O8). In 1999, COGEMA decided to phase out mining at the Christensen Ranch Project, which finally ended on February 29, 2000. A total of just over 4 million pounds of uranium (as U3O8) were recovered from

the Site during mining. COGEMA operations have since concentrated on groundwater restoration, projected for completion in 2001 at the Irigaray Project and in 2005 at the Christensen Ranch Project. Final decommissioning and surface reclamation will follow.

## **2.3 Known Contamination Events**

Records related to spills or other potential contamination events have been maintained since the beginning of commercial operations (1978 for Irigaray Ranch and 1989 for Christensen Ranch). The records are kept in the decommissioning file located in the RSO office so that potentially contaminated locations can be identified during decommissioning. The file includes spill characterization and post-cleanup data, pond leak records, and records of areas designated as restricted areas.

### **2.3.1 Spills**

All solution spills of at least 1,000 gallons or spills with a uranium concentration of at least 5 mg/l (as U3O8) are summarized in Tables A-1 and A-2 of Appendix A for the Irigaray and Christensen Ranch Projects, respectively. The General Location and Spill Maps for each project, located in Attachments 1 and 2, show the numbered locations for these spills. All other recorded spills are considered negligible due to their small volume and low concentration of uranium.

The majority of spills (220 out of a total of 246) were wellfield mining solutions, which includes solutions injected into wells, recovered from wells, and circulated between wells. Most of the wellfield spills contained low concentrations of uranium, with only five exceeding 40 mg/l as U3O8. The maximum concentration was 235 mg/l as U3O8. Ten spills were process solutions from various plant operations. Five of these spills contained concentrated uranium ranging from 159 to 8,579 mg/l as U3O8. Thirteen spills were evaporation pond solutions ranging up to 160 mg/l as U3O8. Three spills were yellowcake slurry. Final surveys will be conducted in the spill areas listed in Appendix A, except Christensen #1, and any soil found to exceed the limits in the approved Decommissioning Plan will be cleaned up. Christensen Spill #1 was located on an access road and the affected soils were removed and the area surveyed as noted later in this section.

The analytical method used to determine the uranium concentrations in soil was EPA 908.1 (Fluorometric) up to 1998 and EPA 200.8 (ICP-MS), thereafter. The equivalent uranium activity concentration was calculated in pCi/g, by multiplying mg/kg by 677 (the conversion factor of the specific activity for natural uranium which is  $6.77 \text{ E-}7$  /gram). The in-house analytical method used to determine the uranium concentrations in water was Bromo PADAP (colorimetric).

Details of the yellowcake spills and those spills that resulted in significant volumes of solution containing concentrated uranium are given below.

Irigaray Spill #1, 12-11-80: A tank thought to contain only potable water was drained outside the Irigaray Project plant and down a draw. The tank also contained a small amount of residual yellowcake that escaped with the water. One drum of contaminated soil was removed as reported to the NRC by letter dated 12-19-80.

Irigaray Spill #61, 10-4-90: Pregnant eluate spilled into the plant from a valve that was inadvertently left open. Approximately 880 gallons flowed through a door at the south side of the plant, of which 450 to 500 gallons were recovered. The solution contained 4,780 mg/l of  $\text{U}_3\text{O}_8$ . Soil cleanup was conducted until Ra-226 concentrations were  $< 5$  pCi/gram as reported to the NRC by letters dated 10-11-90 and 11-9-90.

Irigaray Spill # 102, 8-1-94: A large yellowcake storage tank in the plant collapsed when one of the supporting steel legs penetrated the floor. The tank tore out a section of the plant wall through which 509 gallons of yellowcake slurry and 7,640 gallons of decanted liquid (supernate) flowed outside the building and down an adjacent draw. The spill area was cleaned to meet the existing NRC guidance for soils of 35 pCi/g above background for uranium and 5 pCi/g above background for Ra-226. Spill reports and cleanup information was submitted to the NRC on 8-8-94 and 3-27-95. This area will be closely scrutinized during monitoring and cleanup, since some contamination likely remains.

Irigaray Spill #103, 8-15-94: A broken line leaked 1,000 gallons of yellowcake decant solution onto the ground next to the plant. The solution was being pumped from the yellowcake thickener tank in

the plant to a nearby pond and contained 159.4 mg/l of U<sub>3</sub>O<sub>8</sub>. No cleanup was conducted at the time because a soil sample analysis showed a low concentration of Ra-226.

Irigaray Spill # 124, 8-1-95: 1,500 gallons of resin strip acid solution was spilled from a pipeline that was inadvertently removed from an evaporation pond. The solution contained 8,579 mg/l of U<sub>3</sub>O<sub>8</sub>. No cleanup was conducted at the time because a soil sample analysis showed a Ra-226 concentration of 5.3 pCi/g. The uranium concentration in soil was 550 pCi/g.

Irigaray Spill #135, 4-22-97: Brine from a reverse osmosis filtration unit was spilled from a pipeline removed from an evaporation pond. It was estimated that all but 2,000 gallons of the brine flowed back into the pond. The solution contained 237.7 mg/l of U<sub>3</sub>O<sub>8</sub>. No cleanup was conducted at the time because a soil sample analysis showed low concentrations of uranium and Ra-226.

Christensen Spill # 1, 4-14-89: Three streaks of yellowcake slurry, up to 600 feet long, leaked from a process-water tank being transported by truck. The leak occurred on the access road between the Irigaray Project and Christensen Ranch Project. Affected soils at the spill locations were removed and the residual soils surveyed to meet the alpha release limits, as reported to the NRC by letter on 4-17-89.

Christensen Spill #20, 7-14-94: A failed hose connection leaked 2,500 gallons of recovery solution from well 4P78-2, in Mine Unit 4. The solution contained 235 mg/l of U<sub>3</sub>O<sub>8</sub>. No cleanup was conducted at the time because soil sample analysis showed low concentrations of uranium and Ra-226.

### **2.3.2 Pond Liner Leaks**

All evaporation ponds have been inspected weekly during operations. Any leaks discovered during the inspection were reported, and documented. The following ponds have documented leaks, which resulted from small holes in the synthetic liners: Pond IR-1 (7-24-98), Pond IR-C (7-7-80) Pond IR-D (3-20-92), Pond IR-E (7-28-90), Pond IR-RA (3-19-81), Pond CR-1 (2-5-97), Pond CR-4 (10-22-96, 12-11-96, and 12-11-97). In each case the liner was quickly repaired and any water found in the

detection system was removed. The amount of water that leaked from each of these ponds is not believed to be significant, since they were detected and repaired in a timely manner. During pond decommissioning, all underlying soils and adjacent soils will be surveyed as outlined in Section 7.0.

#### **2.4 Natural Background Radionuclides in Soil**

The geological settings of the Christensen Ranch and Irigaray Projects may be described as relatively small parcels within the west-central portion of the vast Powder River Basin. Strata at the sites dip northwesterly at about one to two degrees. Regional and local studies provide no evidence that measurable faulting has occurred in the project areas. Because of the local geology and the proximity of the two sites, it is reasonable to assume that the surface soils have similar geochemistry and natural background concentrations of radionuclides.

The data in this section will show that there is no evidence of larger than normal variations in surface soil concentrations as a function of depth or within the permit areas. Some minor outcrops of red, oxidized sandstone exist on the Christensen Ranch, but no anomalously high radionuclide concentrations appear to be present. Extensive gamma exposure rate measurements, especially for Christensen Ranch, support this conclusion. Therefore an attempt has been made to evaluate existing data for each site separately but justify establishing a single background concentration for each radionuclide.

In this analysis, it soon became apparent that the operations, with the exception of a few specific spills, have had no measurable impact on the undisturbed soils. The post-operational data and data from special studies were therefore compiled, although treated separately, and used to support the establishment of natural background concentrations for the sites. While the sampling methods (depth interval, composite samples vs. single-point samples, etc.) do not conform with the proposed verification sampling method described in Section 7.2 of this report, it may be argued that this is not a realistic criterion for a sampling program designed to determine baseline conditions. Unless it can be demonstrated that the variation in natural background concentrations in soil is spatially dependent, all sampling methods should give identical results.

The data presented in this section show that variations are similar to those expected, especially when one considers that several different laboratories were used for the analyzes over the sampling interval of 22 years. While the radiological analytical methods have not changed significantly over this time period, calibration biases arising in part from different sources of standard solutions exist. It has been our experience that laboratory errors, along with the variation in soil concentration, and the statistical nature of radioactive decay normally results in background data sets having a coefficient of variation of between 0.5 and 1.5. It will be shown that this is true for these sites as well.

Natural background radionuclide soil sample results are available for the Irigaray and Christensen Ranch Projects. For Irigaray, pre-operations soil samples are limited to samples taken at environmental monitoring stations primarily located away from the wellfield production units. Three of the fifteen stations were located near the processing plant and evaporation ponds area. For the Christensen Ranch Project, an extensive pre-operations sampling program was conducted according to the NRC Reg. Guide 4.14, Radiological Effluent and Environmental Monitoring at Uranium Mills. Soil sampling and gamma exposure rate measurements were conducted throughout the potentially affected area, including the plant site. Samples were also taken at the environmental monitoring stations. All samples were analyzed for natural uranium, Ra-226, Th-230, and Pb-210. Where gross alpha analyses were done, values are reported. Standard Operating Procedure ENV-8 specifies that a ten-sample composite be prepared at each environmental monitoring station from a 10-ft by 10-ft area. Each sample was taken from the top 5-cm surface soil layer. Analysis for uranium was done by a fluorometric method while the other radionuclides were analyzed using radiochemical methods.

Background soil samples were collected at Irigaray Project from 1977 through 1981, and at the Christensen Ranch Project in 1986 and 1987. The Irigaray data were presented in the Revised Application for Renewal of License, October 1985 (1985 Application) and the Christensen Ranch Amendment Application, January 1988 (1988 Application), but no background levels were proposed. Additional samples were taken to a depth of 30 cm in the active wellfield areas and undeveloped production areas in November 1986 at Irigaray as part of a 1987 unpublished

environmental audit report (1987 Report).

Surface soil samples and gamma-ray measurements taken within the wellfield areas do not indicate the presence of surface outcrops of ore or other radiation anomalies. The data also indicate that operations have not impacted the soils on these sites. In fact, post-operations soil sample concentration results for background constituents will be shown to be less, in most cases, than for pre-operations data. In some cases, the variation may arise from the location sampled. However, in most cases, it is believed to arise from small biases in laboratory analyses. In order to obtain the best estimate of the background soil concentrations, we have presented the pre-operations and post-operations data for each site. Some data have been rejected when known local spills may have influenced the results. Using all available data, arguments are made to support the proposed background values. Following the directive of the NRC, the background values are derived from the mean concentrations of the constituents in soil. In this analysis, some consideration has been made for the large variations, as a percentage of the mean, that are evident.

The proposed soil concentration background values are presented in Table 2-1. Supporting discussions for these values are in subsequent sections.

**Table 2-1 Proposed Background Concentrations**

Site	Uranium (pCi/g)	Ra-226 (pCi/g)	Th-230 (pCi/g)	Pb-210 (pCi/g)
Irigaray	2	2	2.5	1.2
Christensen Ranch	2	2	2.5	1.2

#### **2.4.1 Irigaray Pre-Operations Background Sample Results**

Pre-operations background soil samples were taken at environmental monitoring stations IR-1 through IR-15 within and around the mine permit area. It is not known whether the samples were composite samples or the exact depth of the sample. The samples were analyzed by Controls for Environmental Pollution Laboratories. They reported a MDA of 0.5 pCi/g for U-nat, Ra-226, and

Th-230 and 0.1 pCi/g for Pb-210. The data are presented in Table 2-2 with the sample locations shown in Figure 2-1. The samples were taken between June 1977 and September 1978, and were analyzed for uranium, Ra-226, Th-230, Pb-210, and gross alpha.

Additional samples were taken as a part of an environmental audit (1987 Report) in Production Units 6 through 9 in November 1986. Mining operations had started at the Irigaray Project by this date but not in these production units. The locations of Production Units 6 through 9 are shown in Figure 2-2 of this report. The samples were taken by Canonie Environmental and analyzed for Ra-226 and Th-230 as presented in Table 2-2 with sample IDs, P6-51, P7-51, P7-52, P8-51, and P9-51. The first digit in the sample ID indicates the production unit number. The samples were taken to a depth of 30 cm and analyzed for Ra-226 and Th-230 by Energy Laboratories, Inc. No analytical method was reported. Abnormally high uranium concentration results were also reported by the laboratory and labeled "qualitative only". The Induced Coupled Argon Plasma (ICAP) method was used for elemental analysis, including uranium. The element tin interferes with the uranium result when using the ICAP method, rendering the uranium results of little value. These uranium results were rejected and are not reported in Table 2-2.

Since some of the sample locations in Table 2-2 were sampled quarterly under the environmental monitoring program while others were sampled only once, the mean concentration at each location was calculated and then the mean and standard deviation calculated for all the locations. Five of the 20 sample locations (Samples P6...P9...) were within the mineralized production units but no significant differences in the radionuclide content of the samples are apparent. The mean and standard deviation for uranium, Ra-226, Th-230, and Pb-210 for all samples are  $0.5 \pm 0.2$ ,  $1.7 \pm 0.7$ ,  $3.2 \pm 1.2$ , and  $1.3 \pm 0.7$  pCi/g, respectively. The mean and standard deviation of the gross alpha measurements are  $7.1 \pm 3.4$  pCi/g. The standard deviation of the mean values is significantly smaller than the standard deviation of all reported measurements.

#### **2.4.2 Christensen Ranch Pre-Operations Background Sample Results**

The data provided in Table 2-3 for the Christensen Ranch Project is from a pre-mining radiological assessment. The samples were collected according to NRC Regulatory Guide 4.14 in October 1986

**Table 2-2 Pre-Operational Soil Sample Results for Irigaray Project**

Sample ID	Date	Uranium ug/g	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g	Gross Alpha pCi/g
IR-1 (old)	Jun-77	1.00	0.68	0.4 ± 1.2	2.8 ± 0.6	-	14.0 ± 7
IR-1 (old)	Sep-77	0.86	0.58	0.84 ± 0.08	-	-	5.6 ± 1
IR-1 (old)	Mar-78	0.48	0.32	0.71 ± 0.06	-	-	15.0 ± 2
IR-1 (old)	May-78	1.70	1.15	2.9 ± 0.03	-	1.5 ± 0.2	7.0 ± 1.1
IR-1 (old)	Jul-78	0.40	0.27	3 ± 0.5	-	0.62 ± 0.1	4.1 ± 0.9
IR-1 (old)	Sep-78	0.05	0.03	1.9 ± 0.3	-	2.2 ± 0.1	5.2 ± 1.1
IR-1(mean)			0.51	1.63	2.8	1.44	8.5
IR-2	Jun-77	1.00	0.68	0.0 ± 1.3	3.0 ± 0.6	-	27.0 ± 8
IR-2	Sep-77	0.89	0.60	1.0 ± 0.09	-	-	8.8 ± 1.4
IR-2	Mar-78	0.42	0.28	0.54 ± 0.05	-	-	18.0 ± 3
IR-2	May-78	1.00	0.68	0.1 ± 0.3	-	0.8 ± 0.1	33.0 ± 5
IR-2	Jul-78	0.30	0.20	1.4 ± 0.5	-	0.57 ± 0.1	6.2 ± 1.2
IR-2	Sep-78	0.38	0.26	2.1 ± 0.4	-	1 ± 0.1	5.5 ± 1.5
IR-2(mean)			0.45	0.9	3.0	0.8	16.4
IR-3	Jun-77	1.00	0.68	0.4 ± 1.3	4.1 ± 0.7	-	9.7 ± 4.8
IR-3	Sep-77	0.60	0.41	0.61 ± 0.04	-	-	6.5 ± 1.1
IR-3	Mar-78	0.56	0.38	0.89 ± 0.1	-	-	9.3 ± 4
IR-3	May-78	0.70	0.47	2 ± 0.3	-	1.9 ± 0.2	9.5 ± 1.5
IR-3	Jul-78	0.70	0.47	1.9 ± 0.4	-	1.44 ± 0.1	2.3 ± 1.2
IR-3	Sep-78	0.59	0.40	2.6 ± 0.3	-	1.3 ± 0.1	1.7 ± 1.3
IR-3(mean)			0.47	1.40	4.1	1.55	6.5
IR-4 (old)	Jun-77	2.00	1.35	0.7 ± 1.4	1.2 ± 0.5	-	19.0 ± 7
IR-4 (old)	Sep-77	0.70	0.47	0.87 ± 0.05	-	-	7.0 ± 1.1
IR-4 (old)	Mar-78	0.31	0.21	0.57 ± 0.08	-	-	5.8 ± 1.5
IR-4 (old)	May-78	0.80	0.54	2.7 ± 0.4	-	2.8 ± 0.2	12.0 ± 2
IR-4 (old)	Jul-78	0.40	0.27	2.9 ± 0.5	-	3.33 ± 0.2	6.8 ± 1.2
IR-4 (old)	Sep-78	0.67	0.45	2.0 ± 0.3	-	2.5 ± 0.2	3.1 ± 0.9
IR-4(mean)			0.55	1.62	1.2	2.88	9.0
IR-5	Jun-77	2.00	1.35	0.6 ± 1.1	2.0 ± 0.5	-	12.1 ± 5.4
IR-5	Sep-77	0.67	0.45	0.94 ± 0.08	-	-	6.0 ± 1.1
IR-5	Mar-78	0.24	0.16	0.51 ± 0.05	-	-	5.4 ± 1.6
IR-5	May-78	0.70	0.47	2.1 ± 0.3	-	0.8 ± 0.1	7.8 ± 1.5
IR-5	Jul-78	0.40	0.27	2.2 ± 0.5	-	0.31 ± 0.1	10.0 ± 2
IR-5	Sep-78	0.91	0.62	2.2 ± 0.3	-	0.7 ± 0.1	3.7 ± 1.2
IR-5(mean)			0.56	1.43	2.0	0.60	7.5
IR-6	Mar-78	0.42	0.28	0.29 ± 0.05	-	-	5.2 ± 0.9
IR-6	May-78	0.70	0.47	1.9 ± 0.3	-	2.6 ± 0.2	9.0 ± 1.3
IR-6	Jul-78	0.40	0.27	1.9 ± 0.3	-	1.38 ± 0.1	8.5 ± 1.2
IR-6	Sep-78	0.32	0.22	1.2 ± 0.4	-	1.7 ± 0.2	2.9 ± 0.8
IR-6(mean)			0.31	1.32	-	1.89	6.4

**Table 2-2 Pre-Operational Soil Sample Results for Irigaray Project**

Sample ID	Date	Uranium ug/g	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g	Gross Alpha pCi/g	
IR-7	Mar-78	0.29	0.20	0.43 ± 0.04	-	-	3.9 ± 0.8	
IR-7	May-78	0.50	0.34	2.5 ± 0.3	-	1.5 ± 0.2	8.3 ± 1.3	
IR-7	Jul-78	0.20	0.14	1.4 ± 0.3	-	0.63 ± 0.1	3.2 ± 0.8	
IR-7	Sep-78	0.32	0.22	2.1 ± 0.4	-	1.6 ± 0.2	2.3 ± 0.8	
IR-7(mean)			0.22	1.61	-	1.24	4.4	
IR-8	Mar-78	0.50	0.34	0.53 ± 0.05	-	-	4.3 ± 0.9	
IR-8	May-78	0.80	0.54	1.3 ± 0.3	-	0.4 ± 0.1	7.7 ± 1.8	
IR-8	Jul-78	0.30	0.20	4.0 ± 0.6	-	0.18 ± 0.1	4.8 ± 0.9	
IR-8	Sep-78	0.62	0.42	1.6 ± 0.5	-	0.3 ± 0.3	2.2 ± 0.8	
IR-8(mean)			0.38	1.86	-	0.29	4.8	
IR-9	May-78	1.70	1.15	2.2 ± 0.4	-	0.4 ± 0.1	15.0 ± 3	
IR-9	Jul-78	0.50	0.34	3 ± 0.6	-	0.22 ± 0.1	6.1 ± 1.2	
IR-9	Sep-78	0.92	0.62	3.1 ± 0.4	-	0.9 ± 0.2	4.4 ± 1.3	
IR-9(mean)			0.70	2.77	-	0.51	8.5	
IR-10	Mar-78	0.61	0.41	0.54 ± 0.05	-	-	29.0 ± 2	
IR-10	May-78	0.70	0.47	1.5 ± 0.1	-	1 ± 0.2	5.3 ± 1.4	
IR-10	Jul-78	0.50	0.34	0.9 ± 0.4	-	0.14 ± 0.1	5.2 ± 1	
IR-10	Sep-78	1.38	0.93	0.3 ± 0.4	-	0.4 ± 0.1	2.1 ± 0.9	
IR-10(mean)			0.54	0.81	-	0.51	10.4	
IR-11(mean)		Sep-78	1.30	0.88	3.1 ± 1.1	-	2.2 ± 0.2	3.0 ± 1
IR-12(mean)		Sep-78	1.45	0.98	2.6 ± 0.4	-	0.9 ± 0.2	3.2 ± 1
IR-14	May-78	1.00	0.68	2.5 ± 0.3	-	0.7 ± 0.1	7.3 ± 1.2	
IR-14	Jul-78	0.50	0.34	2.0 ± 0.6	-	0.44 ± 0.1	9.6 ± 1.3	
IR-14	Sep-78	0.58	0.39	2.9 ± 0.6	-	2.0 ± 0.2	3.3 ± 0.9	
IR-14(mean)			0.47	2.47	-	1.05	6.7	
IR-15	Jul-78	0.50	0.34	2.2 ± 0.5	-	2.76 ± 0.2	5.2 ± 0.9	
IR-15	Sep-78	0.40	0.27	1.9 ± 0.4	-	2.3 ± 0.2	2.1 ± 0.8	
IR-15(mean)			0.30	2.05	-	2.53	3.7	
P6-51	Jul-86			0.90 ± 0.2	3.2 ± 0.9			
P7-51	Jul-86			0.30 ± 0.2	4.9 ± 1.2			
P7-52	Jul-86			2.10 ± 0.3	3.3 ± 1			
P8-51	Jul-86			1.60 ± 0.3	3.0 ± 0.9			
P9-51	Jul-86			1.90 ± 0.3	4.9 ± 1.2			
Mean			0.5	1.7	3.2	1.3	7.1	
Std. Dev.			0.2	0.7	1.2	0.7	3.4	



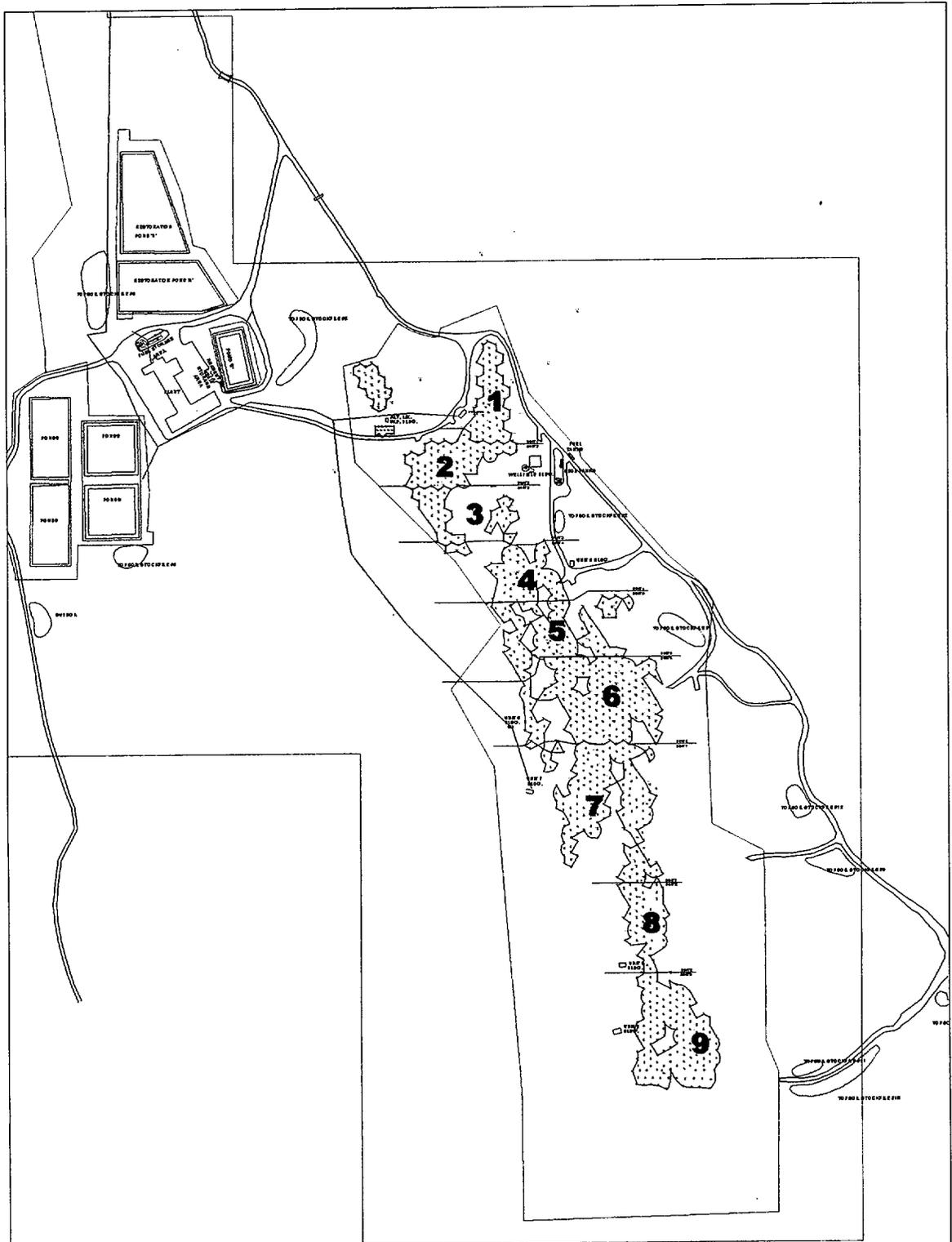


Figure 2-2 Irigaray Project Production Units 1 - 9

500 0 500 Feet



and July 1987 and were analyzed for uranium, Ra-226, Th-230, and Pb-210 by CORE Laboratories using a QA program conforming to NRC guidance. The regulatory guide specifies that surface samples should be 0-5 cm in depth. The sampling locations, as specified in NRC Reg. Guide 4.14, include samples taken above ore trends, along transects of the four predominant downwind directions from the proposed plant center, and at each of the environmental monitoring stations. The locations of the environmental monitoring stations are shown in Figure 2-3.

Ore trend surface soil samples were taken along transects at approximately 300-meter intervals. Sample locations are shown in Figure 2-3. The results for the ore trend samples are given in Table 2-3 with Sample ID beginning with OT (ore trend). A total of 61 soil sample results for the ore trends are used in making up the data set. One sample, OT-51 was considered an outlier since the results for uranium, Ra-226, Th-230, and Pb-210 were reported as 18, 18.7, 82, and 22.8 pCi/g, respectively.

Surface soil samples were also taken at 300-meter intervals along the four predominant downwind vectors, beginning at the proposed plant center. The four directions chosen were NW, NE, E, and SE. These samples are listed as NW-1 through NW-5, NE-1 through NE-5, etc. in Table 2-3, with the sample number increasing as the location is farther from the plant center.

Four samples were taken at each of the environmental monitoring stations (AS-1 through AS-6). The initial sample was a 0-5 cm composite sample. The remaining three samples were sequential 31-cm samples to a total depth of approximately one meter. The sample results for the top surface sample are presented in Table 2-3. The entire set of samples is given in Table 2-4. The data in Table 2-4 suggest that the radionuclide variation with depth is only statistical in nature.

The reported uranium concentrations for all nine samples analyzed for uranium from the environmental monitoring stations on September 10, 1987 by Core Laboratories were  $< 0.2$  pCi/g, which is the reported minimum detectable concentration. These low values are in contrast to the post-operations data for the air sampling stations discussed in Section 2.4.4, where all values exceed the minimum detectable concentration of 0.2 pCi/g. The data presented in Table 2-3 indicate a bimodal distribution. Sixteen samples were reported as  $< 0.2$  pCi/g while 33 samples were reported

**Table 2-3 Pre-Operational Soil Sample Results for Ore Transects,  
Four Directions, and Air Sampling Stations at Christensen Ranch Project**

Sample I.D.	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
OT-1	-	2.6 ± 0.4	-	-
OT-2	-	3.2 ± 0.5	-	-
OT-3	-	3.1 ± 0.4	-	-
OT-4	-	2.8 ± 0.4	-	-
OT-5	-	3.2 ± 0.4	-	-
OT-6	-	6.8 ± 0.6	-	-
OT-7	-	3.9 ± 0.5	-	-
OT-8	-	4.7 ± 0.5	-	-
OT-9	-	4.3 ± 0.5	-	-
OT-10	4.0	3.7 ± 0.7	1.9 ± 0.2	0.7 ± 1.0
OT-11	-	2.9 ± 0.4	-	-
OT-12	-	3 ± 0.4	-	-
OT-13	-	3.1 ± 0.4	-	-
OT-14	-	3.4 ± 0.5	-	-
OT-15	3.5	2.2 ± 0.6	2.2 ± 0.2	0.3 ± 0.9
OT-16	-	3.1 ± 0.4	-	-
OT-17	-	3.9 ± 0.5	-	-
OT-18	-	2.8 ± 0.4	-	-
OT-19	-	3.9 ± 0.5	-	-
OT-20	-	4.2 ± 0.5	-	-
OT-25	1.2	1.9 ± 0.4	-	-
OT-26	<0.2	2.4 ± 0.5	-	-
OT-27	<0.2	1.9 ± 0.4	-	-
OT-28	<0.2	1.1 ± 0.4	-	-
OT-29	2.3	2 ± 0.4	-	-
OT-33	1.2	1.4 ± 0.4	-	-
OT-34	1.7	2 ± 0.4	-	-
OT-35	1.4	2.1 ± 0.4	-	-
OT-36	0.6	2.8 ± 0.4	-	-
OT-42	<0.2	2.5 ± 0.5	1.3 ± 0.4	4.7 ± 0.9
OT-43	2.3	1.6 ± 0.4	-	-
OT-44	3.5	2.4 ± 0.4	-	-
OT-45	3.5	2.2 ± 0.4	-	-
OT-46	2.3	1.9 ± 0.4	-	-
OT-47	2.6	1.7 ± 0.4	-	-
OT-48	3.2	1.5 ± 0.4	-	-
OT-49	2.6	1.6 ± 0.4	-	-
OT-50	3.5	1.1 ± 0.4	-	-
OT-51	2.3	1.3 ± 0.4	-	-
OT-53	<0.2	1.7 ± 0.4	-	-
OT-54	<0.2	1.9 ± 0.4	-	-
OT-55	4.7	1.2 ± 0.3	-	-
OT-56	0.6	2.3 ± 0.5	-	-
OT-57	<0.2	1.5 ± 0.4	-	-
OT-58	1.2	0.7 ± 0.3	-	-
OT-59	1.7	1.4 ± 0.4	-	-
OT-60	1.2	1.9 ± 0.4	-	-
OT-61	1.7	1.9 ± 0.4	-	-

**Table 2-3 Pre-Operational Soil Sample Results for Ore Transects,  
Four Directions, and Air Sampling Stations at Christensen Ranch Project**

Sample I.D.	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
OT-62	1.2	3.3 ± 0.5	1.3 ± 0.4	3.4 ± 0.8
OT-63	5.3	1.7 ± 0.4	-	-
OT-65	1.7	1.5 ± 0.4	-	-
OT-65A	2.3	1.4 ± 0.4	-	-
OT-66	<0.2	1.4 ± 0.4	-	-
OT-67	1.7	1.3 ± 0.4	-	-
OT-68	3.5	2.2 ± 0.4	-	-
OT-69	2.3	1.7 ± 0.4	-	-
OT-70	2.3	1.3 ± 0.4	-	-
OT-74	3.5	1.8 ± 0.4	-	-
OT-75	1.2	3.1 ± 0.5	6.9 ± 0.7	6 ± 0.9
OT-76	<0.2	2.8 ± 0.4	-	-
OT-77	<0.2	1.7 ± 0.4	-	-
NW-1	-	3.2 ± 0.5	-	-
NW-2	-	3.8 ± 0.5	-	-
NW-3	-	3.6 ± 0.5	-	-
NW-4	-	4 ± 0.5	-	-
NW-5	4.7	3.9 ± 0.8	2.5 ± 0.2	0.4 ± 1.0
NE-1	-	2.3 ± 0.4	-	-
NE-2	-	3.6 ± 0.5	-	-
NE-3	-	4 ± 0.5	-	-
NE-4	-	3.8 ± 0.5	-	-
NE-5	7.7	3.8 ± 0.7	1.7 ± 0.2	0.4 ± 1.0
E-1	-	2.8 ± 0.4	-	-
E-2	-	1.6 ± 0.3	-	-
E-3	-	3.4 ± 0.5	-	-
E-4	-	3.4 ± 0.5	-	-
E-5	-	3.1 ± 0.5	-	-
SE-1	-	2.3 ± 0.4	-	-
SE-2	-	3.8 ± 0.4	-	-
SE-3	-	3.9 ± 0.7	-	-
SE-4	-	3.5 ± 0.5	-	-
SE-5	-	3.4 ± 0.5	-	-
AS-1 (0 - 5cm)	<0.2	1.8 ± 0.3	2 ± 0.1	1.6 ± 0.6
AS-2 (0 - 5cm)	<0.2	1.8 ± 0.3	2 ± 0.1	1.1 ± 0.5
AS-3 (0 - 5cm)	<0.2	1.5 ± 0.2	2.8 ± 0.3	0.9 ± 0.5
AS-4 (0 - 5cm)	<0.2	1.1 ± 0.2	1.1 ± 0.2	1.5 ± 0.5
AS-5 (0 - 5cm)	<0.2	1.7 ± 0.2	0.8 ± 0.1	1 ± 0.5
AS-6 (0 - 5cm)	<0.2	1.3 ± 0.2	1.1 ± 0.2	0.7 ± 0.5
Mean*	2.6	2.6	2.1	1.7
Std. Dev.	1.5	1.1	1.6	1.8

\* < 0.2 pCi/g values omitted from mean and standard deviation values

**Table 2-4 Pre-Operational Soil Sample Results taken at depth  
at Christensen Ranch Project Air Sampling Stations**

Sample ID	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
AS-1 (0 - 5cm)	< 0.2	1.8 ± 0.3	2 ± 0.1	1.6 ± 0.6
AS-1 (6 -37cm)	-	1.2 ± 0.2	-	-
AS-1 (38 - 69cm)	-	1 ± 0.2	-	-
AS-1 (70 - 100cm)	-	1.7 ± 0.2	-	-
AS-2 (0 - 5cm)	< 0.2	1.8 ± 0.3	2 ± 0.1	1.1 ± 0.5
AS-2 (6 -37cm)	-	1.3 ± 0.2	-	-
AS-2 (38 - 69cm)	-	0.8 ± 0.2	-	-
AS-2 (70 - 100cm)	-	0.9 ± 0.2	-	-
AS-3 (0 - 5cm)	< 0.2	1.5 ± 0.2	2.8 ± 0.3	0.9 ± 0.5
AS-3 (6 -37cm)	-	1.3 ± 0.2	-	-
AS-3 (38 - 69cm)	-	1.3 ± 0.2	-	-
AS-3 (70 - 100cm)	-	1.4 ± 0.2	-	-
AS-4 (0 - 5cm)	< 0.2	1.1 ± 0.2	1.1 ± 0.2	1.5 ± 0.5
AS-4 (6 -37cm)	-	1.3 ± 0.2	-	-
AS-4 (38 - 69cm)	-	1.4 ± 0.2	-	-
AS-4 (70 - 100cm)	-	1.4 ± 0.2	-	-
AS-5 (0 - 5cm)	< 0.2	1.7 ± 0.2	0.8 ± 0.1	1 ± 0.5
AS-5 (6 -37cm)	< 0.2	1.2 ± 0.2	0.8 ± 0.1	1 ± 0.5
AS-5 (38 - 69cm)	< 0.2	1.2 ± 0.2	5 ± 0.5	1.1 ± 0.5
AS-5 (70 - 100cm)	< 0.2	1.3 ± 0.2	2.4 ± 0.3	1.4 ± 0.5
AS-6 (0 - 5cm)	< 0.2	1.3 ± 0.2	1.1 ± 0.2	0.7 ± 0.5
AS-6 (6 -37cm)	-	1.9 ± 0.2	-	-
AS-6 (38 - 69cm)	-	1.4 ± 0.2	-	-
AS-6 (70 - 100cm)	-	1.1 ± 0.2	-	-
Mean		1.3	2.0	1.1
Std. Dev.		0.3	0.6	0.3

above 1 pCi/g. Only two samples have reported values between these two groupings. Sediment data from Willow Creek taken during the pre-operations period also revealed uranium concentrations typically above 1 pCi/g. Based on all available data, it is concluded that it is improbable that background samples taken from this site will have uranium concentrations  $< 0.2$  pCi/g. We therefore consider these values resulting from laboratory error and have omitted these nine  $< 0.2$  pCi/g results reported in Table 2-3 in determining the mean and standard deviation of the results. The mean and standard deviation of the sample results in Table 2-3 for uranium, Ra-226, Th-230, and Pb-210 are  $2.6 \pm 1.5$ ,  $2.6 \pm 1.1$ ,  $2.1 \pm 1.6$ , and  $1.7 \pm 1.8$  pCi/g, respectively.

Pre-operations data for the Christensen Ranch Project is very complete with most of the samples taken within or near the wellfields. The data show a slight decrease in the environmental monitoring stations Ra-226 concentration, compared to the other data points that are within or very near the ore trends. However, the Th-230 and Pb-210 concentrations appear to be similar to those in the ore trend areas. As mentioned above, we have rejected the reported less than detectable ( $< 0.2$  pCi/g) uranium concentrations from the analysis.

A total of 283 gamma exposure rate measurements were made using either a hand-held Eberline PRM-6 with a LEG-1 scintillation cell or a Geometrics scintillation counter held at a height of approximately one meter above the ground surface. Measurements were made at 217 sites along the ore-trend transects, 60 sites along the four predominant wind direction vectors, and six at the air sampling stations. The exposure rates varied from 11 to 23  $\mu\text{R/h}$ , averaging 15  $\mu\text{R/h}$ . The variation appeared to be random and within the expected normal variation in background levels, considering the precision of the measurement method. This suggests that no surface soil radionuclide anomalies exist in the ore trend areas.

#### **2.4.3 Irigaray Project Post-Operations Sample Results**

Samples taken at environmental monitoring stations after production began provide a measure of the impact of the operations on the environment and are given in Table 2-5. The stations were sampled over two periods. The sample results from the first period (July 1979 thru July 1981) included all 15 stations around the site (IR-1 through IR-15). For the second period, stations IR-1 and IR-3 thru IR-

Table 2-5 Post-Operational Soil Sample Results at Irigaray Project

Sample ID	Date	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g	Gross Alpha pCi/g
IR-1 (old)	Jul-79	0.61	2.7 ± 0.5	0.03 ± 0.01	1.1 ± 0.1	5.8 ± 0.6
IR-1 (old)	Jul-80	1.46	0.39 ± 0.06	1.47 ± 0.05	0 ± 0.1	5.0 ± 1
IR-1 (old)	Jul-81	0.05	< 0.05	< 0.1	< 0.1	1.2 ± 0.4
IR-1 (old)	1987	< 0.1	1.2	3.1	< 0.3	-
IR-1 (old)	1988	3.10	2.2 ± 0.2	2.7 ± 0.2	0.7 ± 0.33	-
IR-1 (old)	1989	2.44	1.3 ± 0.1	< 0.02	< 0.1	-
IR-1 (old)	1990	3.60	1.3 ± 0.1	1.2 ± 0.6	< 0.2	-
IR-1 (old)	1991	6.40	1.4 ± 0.1	< 0.04	0.9 ± 0.5	-
IR-1 (old)	1992	2.30	1.4 ± 0.1	1.2 ± 1.2	1.1 ± 0.4	-
IR-1 (old)	1993	1.70	1.2 ± 0.1	0.2 ± 0.1	0.5 ± 0.2	-
IR-1 (old)	1994	3.40	1.1 ± 0.1	< 0.02	0.2 ± 0.2	-
IR-1(old) (mean)		2.51	1.42	1.41	0.64	4.00
IR-1(new)	1995	2.80	1.30 ± 0.4	0.80 ± 0.5	0.00 ± 0.6	-
IR-1(new)	1996	2.50	1.20 ± 0.1	0.70 ± 0.2	0.60 ± 0.3	-
IR-1(new)	Jun-97	2.80	1.6 ± 0.1	0.83 ± 0.13	0.8 ± 0.2	-
IR-1(new)	Jul-98	5.48	1.3 ± 0.1	0.8 ± 0.1	0.7 ± 0.2	-
IR-1(new)	Jun-99	3.38	1.1 ± 0.11	0.93 ± 0.1	1.01 ± 0.21	-
IR-1(new)	Jun-00	4.50	1.32 ± 0.12	0.9 ± 0.14	1.52 ± 0.4	-
IR-1(new) (mean)		3.58	1.30	0.83	0.77	-
IR-2	Jul-79	1.49	2.7 ± 0.5	0.03 ± 0.01	1.1 ± 0.1	5.8 ± 0.6
IR-2	Jul-80	0.41	0.34 ± 0.04	0.24 ± 0.05	0.6 ± 0.41	2.0 ± 0.6
IR-2	Jul-81	< 0.03	1.2 ± 0.2	0.04 ± 0.02	< 0.1	6.7 ± 1.6
IR-2 (mean)		0.95	1.41	0.10	0.85	4.83
IR-3	Jul-79	0.47	2.9 ± 0.5	0.04 ± 0.01	1.7 ± 0.1	1.5 ± 0.3
IR-3	Jul-80	0.20	1.59 ± 0.25	0.08 ± 0.02	1.21 ± 0.42	1.7 ± 0.6
IR-3	Jul-81	< 0.03	0.3 ± 0.1	< 0.05	0.1	2.5 ± 1.1
IR-3	1987	< 0.1	1.1	6.4	< 0.3	-
IR-3	1988	2.40	1.9 ± 0.1	2.2 ± 0.4	0.38 ± 0.3	-
IR-3	1989	5.92	1.4 ± 0.1	0.4 ± 0.4	1.3 ± 0.2	-
IR-3	1990	5.00	0.9 ± 0.1	1 ± 0.6	2.4 ± 0.2	-
IR-3	1991	**	0.7 ± 0.1	< 0.04	1.1 ± 0.6	-
IR-3	1992	1.20	1 ± 0.1	1.6 ± 1.2	1 ± 0.4	-
IR-3	1993	1.80	0.8 ± 0.1	0.2 ± 0.1	0.3 ± 0.2	-
IR-3	1994	2.70	0.7 ± 0.1	< 0.02	< 0.02	-
IR-3	1995	0.02	1.1 ± 0.4	0.5 ± 0.4	2.1 ± 1.1	-
IR-3	1996	*	1.3 ± 0.2	0.7 ± 0.2	1.4 ± 0.4	-
IR-3	Jun-97	*	1.1 ± 0.1	0.71 ± 0.18	0.5 ± 0.2	-
IR-3	Jul-98	*	1.2 ± 0.1	1.5 ± 0.1	0.4 ± 0.2	-
IR-3	Jun-99	*	0.96 ± 0.11	0.55 ± 0.08	0.44 ± 0.19	-
IR-3	Jun-00	*	0.83 ± 0.1	0.64 ± 0.12	0.5 ± 0.18	-
IR-3 (mean)		2.19	1.16	1.18	0.99	1.90
IR-4 (old)	Jul-79	0.34	2.5 ± 0.5	0.09 ± 0.01	2 ± 0.1	7.5 ± 0.7
IR-4 (old)	Jul-80	0.34	0.85 ± 0.07	0 ± 0.02	1.8 ± 0.39	3.2 ± 0.8
IR-4 (old)	Jul-81	< 0.03	1.6 ± 0.2	< 0.05	3.2 ± 1.3	6.6 ± 1.3
IR-4 (old)	1987	1.80	1.3	2.9	0.8	-
IR-4 (old)	1988	1.10	1.7 ± 1	1.6 ± 0.2	0.9 ± 0.35	-
IR-4 (old)	1989	1.61	1.5 ± 0.1	< 0.02	1 ± 0.2	-
IR-4 (old)	1990	1.10	1.1 ± 0.1	0.2 ± 0.2	0.3 ± 0.3	-
IR-4 (old)	1991	6.04	0.9 ± 0.1	< 0.04	0.5 ± 0.5	-
IR-4 (old)	1992	0.04	0.7 ± 0.1	0.6 ± 0.6	1.6 ± 0.4	-
IR-4 (old)	1993	0.20	0.9 ± 0.1	0.2 ± 0.1	0.7 ± 0.2	-
IR-4 (old)	1994	0.80	0.7 ± 0.1	< 0.02	0.2 ± 0.2	-
IR-4(old) (mean)		1.34	1.25	0.82	1.18	5.77

**Table 2-5 Post-Operational Soil Sample Results at Irigaray Project**

Sample ID	Date	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g	Gross Alpha pCi/g
IR-4 (new)	1995	1.40	1.00 ± 0.4	1.90 ± 0.7	2.10 ± 1.1	-
IR-4 (new)	1996	0.50	1.10 ± 0.1	0.80 ± 0.1	<0.1	-
IR-4 (new)	Jun-97	0.45	0.9 ± 0.5	0.52 ± 0.1	1.0 ± 0.2	-
IR-4 (new)	Jul-98	0.63	0.8 ± 0.1	0.5 ± 0.1	1.0 ± 0.2	-
IR-4 (new)	Jun-99	0.43	0.87 ± 0.1	0.52 ± 0.09	1.13 ± 0.21	-
IR-4 (new)	Jun-00	0.53	0.82 ± 0.1	0.65 ± 0.11	1.38 ± 0.39	-
IR-4(new) (mean)		0.66	0.92	0.82	1.32	-
IR-5	Jul-79	0.47	3.2 ± 0.3	0.01 ± 0.01	0.4 ± 0.1	3.0 ± 0.5
IR-5	Jul-80	0.30	0.38 ± 0.04	0.42 ± 0.03	0 ± 0.1	2.5 ± 0.7
IR-5	Jul-81	0.06	0.4 ± 0.1	0.04 ± 0.02	<0.10	1.6 ± 0.4
IR-5	1987	<1.0	1.1	3.9	<0.3	-
IR-5	1988	0.88	1.1 ± 0.2	0.75 ± 0.15	0.25 ± 0.12	-
IR-5	1989	1.22	0.9 ± 0.1	1.1 ± 0.5	<0.1	-
IR-5	1990	0.70	0.7 ± 0.1	0.3 ± 0.3	0.3 ± 0.3	-
IR-5	1991	0.36	0.4 ± 0.1	<0.04	0.5 ± 0.5	-
IR-5	1992	2.40	3.7 ± 0.1	1.2 ± 1.2	0.8 ± 0.4	-
IR-5	1993	0.60	0.7 ± 0.1	<0.02	0.6 ± 0.2	-
IR-5	1994	0.60	2.0 ± 0.2	<0.02	0.4 ± 0.4	-
IR-5	1995	1.40	1.0 ± 0.4	0.5 ± 0.4	0.4 ± 0.9	-
IR-5	1996	0.60	0.7 ± 0.1	0.5 ± 0.1	0.8 ± 0.3	-
IR-5	Jun-97	0.75	0.9 ± 0.1	0.64 ± 0.11	1.1 ± 0.2	-
IR-5	Jul-98	0.76	0.6 ± 0.1	0.6 ± 0.1	0.4 ± 0.2	-
IR-5	Jun-99	0.64	0.7 ± 0.09	0 ± 0.08	0.44 ± 0.19	-
IR-5	Jun-00	0.67	0.67 ± 0.09	0.32 ± 0.07	1.12 ± 0.21	-
IR-5 (mean)		0.78	1.13	0.73	0.54	2.37
IR-6	Jul-79	1.22	1.9 ± 0.3	0.62 ± 0.05	1.9 ± 0.1	7.6 ± 0.7
IR-6	Jul-80	0.87	0.54 ± 0.04	1.28 ± 0.06	1.03 ± 0.45	5.1 ± 1
IR-6	Jul-81	<0.03	0.9 ± 0.1	0.04 ± 0.02	<0.1	1.7 ± 0.4
IR-6	1987	0.80	2.2	4.2	1.3	-
IR-6	1988	1.50	1.9 ± 0.1	2.1 ± 0.2	0.2 ± 0.12	-
IR-6	1989	2.06	2.2 ± 0.1	2.8 ± 0.6	<0.1	-
IR-6	1990	1.10	0.9 ± 0.1	0.2 ± 0.2	0.5 ± 0.3	-
IR-6	1991	5.92	0.6 ± 0.1	<0.04	1.8 ± 0.6	-
IR-6	1992	1.50	0.9 ± 0.1	3.1 ± 2.5	1.2 ± 0.4	-
IR-6	1993	0.70	1 ± 0.1	0.9 ± 0.5	0.2 ± 0.2	-
IR-6	1994	0.80	0.7 ± 0.1	<0.02	0.2 ± 0.2	-
IR-6	1995	1.50	1.3 ± 0.4	0.6 ± 0.5	1.3 ± 1	-
IR-6	1996	0.90	1.1 ± 0.1	0.5 ± 0.1	1 ± 0.3	-
IR-6	Jun-97	1.01	1.8 ± 0.1	0.76 ± 0.12	0.7 ± 0.2	-
IR-6	Jul-98	1.09	1.1 ± 0.01	0.8 ± 0.1	0.6 ± 0.2	-
IR-6	Jun-99	0.72	0.88 ± 0.1	0.42 ± 0.07	0.93 ± 0.2	-
IR-6	Jun-00	0.98	1.07 ± 0.11	0.95 ± 0.16	0.74 ± 0.19	-
IR-6 (mean)		1.42	1.23	1.28	0.91	4.80
IR-7	Jul-79	0.74	2.6 ± 0.4	0.13 ± 0.01	3.2 ± 0.2	5.1 ± 0.6
IR-7	Jul-80	0.37	0 ± 0.05	1.17 ± 0.06	1.36 ± 0.35	6.1 ± 1
IR-7	Jul-81	<0.03	0.7 ± 0.1	<0.05	<0.1	2.6 ± 0.5
IR-7 (mean)		0.56	1.10	0.65	2.28	4.60
IR-8	Jul-79	0.41	1.3 ± 0.4	0.13 ± 0.01	0.4 ± 0.1	3.8 ± 0.5
IR-8	Jul-80	0.42	0 ± 0.05	3.05 ± 0.11	1.09 ± 0.5	7.9 ± 1.2
IR-8	Jul-81	0.03	1.8 ± 0.3	<0.05	0.1	2.5 ± 0.5
IR-8 (mean)		0.29	1.03	1.59	0.53	4.73
IR-9	Jul-79	<0.07	3.1 ± 0.5	0.6 ± 0.04	0.6 ± 0.1	2.6 ± 0.4
IR-9	Jul-80	0.50	0 ± 0.05	0.44 ± 0.04	0.54 ± 0.34	3.1 ± 0.8

Table 2-5 Post-Operational Soil Sample Results at Irigaray Project

Sample ID	Date	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g	Gross Alpha pCi/g
IR-9	Jul-81	<0.03	1.7 ± 0.2	<0.05	<0.1	1.7 ± 0.4
IR-9 (mean)		0.50	1.60	0.52	0.57	2.47
IR-10	Jul-79	0.34	0.3 ± 0.4	0.04 ± 0.01	0.3 ± 0.1	3.5 ± 0.5
IR-10	Jul-80	0.40	0.12 ± 0.03	0.15 ± 0.03	0.47 ± 0.3	3.1 ± 0.8
IR-10	Jul-81	<0.03	<0.05	<0.05	<0.10	1.3 ± 0.3
IR-10 (mean)		0.37	0.21	0.10	0.39	2.63
IR-11	Jul-79	0.41	2.3 ± 0.3	0.03 ± 0.01	1 ± 0.1	6.4 ± 0.6
IR-11	Jul-80	0.61	0.89 ± 0.11	1.59 ± 0.06	0.63 ± 0.21	4.5 ± 0.9
IR-11	Jul-81	0.03	<0.05	<0.05	<0.10	1.3 ± 0.3
IR-11 (mean)		0.35	1.60	0.81	0.82	4.07
IR-12	Jul-79	0.34	1.9 ± 0.3	0.34 ± 0.02	0.9 ± 0.1	3.8 ± 0.5
IR-12	Jul-80	0.52	0.37 ± 0.06	0.54 ± 0.05	0.67 ± 0.24	4.2 ± 0.9
IR-12	Jul-81	0.06	0.6 ± 0.1	<0.05	<0.10	1.7 ± 0.4
IR-12 (mean)		0.31	0.96	0.44	0.79	3.23
IR-13	Jul-79	0.20	1.2 ± 0.3	0.11 ± 0.01	0.6 ± 0.1	4.5 ± 0.6
IR-13	Jul-80	0.39	0.21 ± 0.03	0.23 ± 0.03	2.79 ± 0.3	7.9 ± 1.2
IR-13	Jul-81	0.16	0.7 ± 0.1	<0.05	<0.10	0.8 ± 0.2
IR-13 (mean)		0.25	0.70	0.17	1.70	4.40
IR-14	Jul-79	<0.07	2.9 ± 0.4	0.18 ± 0.02	1 ± 0.1	6.1 ± 0.6
IR-14	Jul-80	0.56	0.34 ± 0.5	0 ± 0.05	0.9 ± 0.31	4.8 ± 0.9
IR-14	Jul-81	0.06	1 ± 0.2	<0.05	<0.1	2.4 ± 0.8
IR-14 (mean)		0.31	1.41	0.09	0.95	4.43
IR-15	Jul-79	0.14	2.8 ± 0.4	0.13 ± 0.01	0.3 ± 0.1	4.8 ± 0.6
IR-15	Jul-80	0.41	0.41 ± 0.05	0.5 ± 0.03	0.61 ± 0.23	8.6 ± 1.2
IR-15	Jul-81	0.07	0.3 ± 0.1	<0.05	<0.1	2.0 ± 0.5
IR-15 (mean)		0.20	1.17	0.32	0.46	5.13
P1-51	Nov-86		5.3 ± 0.3	1.8 ± 1.3		
P1-52	Nov-86		1.9 ± 0.3	2.4 ± 0.9		
P1-53	Nov-86		1.6 ± 0.3	3.3 ± 1.2		
P2-51	Nov-86		1.2 ± 0.2	4.2 ± 1.3		
P2-52	Nov-86		1.7 ± 0.3	1.8 ± 0.9		
P2-53	Nov-86		1.2 ± 0.2	4.9 ± 1.2		
P3-51	Nov-86		0.5 ± 0.1	2.2 ± 0.9		
P3-52	Nov-86		0 ± 0.2	0.9 ± 0.6		
P3-53	Nov-86		1 ± 0.3	2.5 ± 1.1		
P4-51	Nov-86		0.8 ± 0.2	2.9 ± 1.1		
P4-52	Nov-86		1.2 ± 0.2	2.3 ± 0.9		
P4-53	Nov-86		1.1 ± 0.2	2.6 ± 0.9		
P5-51	Nov-86		1.3 ± 0.2	2.6 ± 0.9		
P5-52	Nov-86		1.1 ± 0.2	2.2 ± 0.8		
P5-53	Nov-86		1.1 ± 0.2	3.6 ± 1		
E-51	Nov-86		1.5 ± 0.3	1.9 ± 0.8		
E-52	Nov-86		1.9 ± 0.3	0.9 ± 1.4		
E-53	Nov-86		1.9 ± 0.3	3.6 ± 1.2		
Mean		1.0	1.3	1.7	0.9	4.0
Std. Dev.		1.0	0.8	1.3	0.5	1.2

\* Samples taken in former spill areas not included. Reported values range from 7.03 to 77.2 pCi/g.

\*\* Value of 37.46 pCi/g considered an outlier.

have been sampled annually since 1987. Note that in 1994, stations IR-1, IR-3 and IR-4 were relocated closer to the plant and are labeled "new". The results for all samples were reported in the Semi-Annual Effluent and Monitoring Reports submitted to the NRC for each year. The locations for the Irigaray Project environmental monitoring stations are shown in Figure 2-1, including the original (old) and current (new) locations for IR-1, IR-3 and IR-4. The Irigaray Project post-operations sample data provide results for uranium, Ra-226, Th-230, Pb-210, and gross alpha.

In November 1986, surface soil samples to a depth of 30 cm were taken from the active Production Units 1 through 5, and Wellfield E, located west of Production Unit 1 at the lixiviant pilot test area. These samples were taken as part of the 1987 Report. While the precise sample locations are not known, the locations of the production units are shown in Figure 2-2 of this report. The production unit data contains only the results for Ra-226 and Th-230. Uranium data were provided but labeled "qualitative only" so they have been discarded from the data set.

Because most of the environmental monitoring stations were sampled annually over different periods of time, the mean concentration for each location was calculated. The uranium and other analyses, where less than minimum detectable concentrations were reported, were not included in the calculation of the mean and standard deviation. It is considered unreasonable that these low levels would exist at the site. It should also be noted that most of the minimum detectable values were reported for the July 1981 samples. The mean concentrations for each station were used to determine an arithmetic average and standard deviation for each point. All data are included in Table 2-5. The mean and standard deviation for uranium, Ra-226, Th-230, Pb-210, and gross alpha were calculated to be  $1.0 \pm 1.0$ ,  $1.3 \pm 0.8$ ,  $1.7 \pm 1.3$ ,  $0.9 \pm 0.5$ , and  $4.0 \pm 1.2$  pCi/g, respectively. The reported standard deviation for all sample results would be up to twice as large if the standard deviation were calculated using all measurements. The standard deviation of the mean values at each location can be interpreted as a measure of the spatial variation of the mean concentrations.

As with the pre-operations data for the Irigaray Project, most of the post-operations samples were taken from the environmental monitoring stations. The sample results making up this data set are primarily from two sources, the environmental monitoring stations (IR1 through IR-15) and the 18

sample results from the 1987 Report taken within the wellfield areas. The post-operations data taken within the wellfields show slightly increased levels of Th-230 (mean of 2.6 pCi/g compared to 0.7 pCi/g) compared to the other Irigaray samples but little or no increase in Ra-226 (mean of 1.5 pCi/g compared to 1.2 pCi/g).

#### **2.4.4 Christensen Ranch Post-Operations Background Sample Results**

Post-operations data for the Christensen Ranch Project is limited to four environmental monitoring stations (AS-1, AS-6, AS-5A, and AS-5B) with samples taken annually beginning in 1998. The data have been reported to the NRC in the Semi-Annual Effluent and Monitoring Reports and have been compiled into Table 2-6. Note that sample station AS-5 shown in Figure 2-3, from the pre-operational sampling period, was replaced with stations AS-5A and AS-5B. Both new stations are located near the original AS-5 station but are now upwind (Station 5B) and downwind (Station 5A) of the plant. Post-operational sample results for AS-2, AS-3, and AS-4 were dropped from the post-operations sampling program given in the 1988 Application. Therefore, no post-operational sample results are available from these stations. The post-operations samples were analyzed for uranium, Ra-226, Th-230, and Pb-210. The mean of the data for each location was calculated. Since the same number of data points exist for each sampling location, the standard deviation of the entire data set was calculated. The means and standard deviations for these constituents are  $1.5 \pm 1.5$ ,  $1.5 \pm 0.8$ ,  $1.9 \pm 2.4$ , and  $1.0 \pm 0.5$  pCi/g, respectively.

#### **2.4.5 Discussion and Conclusion**

##### Pb-210 Background

The mean and standard deviation of the pre-operations and post-operations sample results are shown in Table 2-7. Pb-210, being a radon decay product, has the most consistent concentrations. No significant differences are apparent between sites or over sampling time periods. One can only conclude that any radon emissions from operations were not significant enough to produce a measurable increase in radon progeny across the sites. The mean background for Pb-210 is 1.2 pCi/g. Further analyses for Pb-210 during the decommissioning and soil cleanup verification phase of the project will not be made.

**Table 2-6 Post-Operation Soil Sample Results at Christensen Ranch Project**

Sample ID	Date	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
AS-1	1988	1.1	1.8 ± 0.3	11.8 ± 1.7	0.7 ± 0.3
AS-1	1989	1.4	2.2 ± 0.3	1.6 ± 1	1.6 ± 0.4
AS-1	1990	0.6	0.9 ± 0.1	1 ± 0.6	2.2 ± 1.1
AS-1	1991	0.5	1.6 ± 0.1	<0.04	1.5 ± 0.6
AS-1	1992	**8.9	**7.1 ± 0.2	**22.2 ± 4.3	0.8 ± 0.4
AS-1	1993	0.9	3.7 ± 0.1	0.1 ± 0.1	0.5 ± 0.2
AS-1	1994	0.9	1.9 ± 0.2	<0.02	0.6 ± 0.4
AS-1	1995	1	1.4 ± 0.4	1 ± 0.6	0.9 ± 1
AS-1	1996	0.9	0.9 ± 0.1	0.6 ± 0.1	0.9 ± 0.3
AS-1	1997	0.7	0.9 ± 0.1	0.57 ± 0.1	0.5 ± 0.2
AS-1	1998	0.9	1.1 ± 0.1	0.7 ± 0.1	0.8 ± 0.2
AS-1	1999	0.6	0.75 ± 0.09	0.53 ± 0.1	0.58 ± 0.19
AS-1	2000	0.7	0.7 ± 0.09	0.65 ± 0.12	0.66 ± 0.19
Mean		0.9	1.5	1.9	0.9
Std. Dev.		0.3	0.9	3.5	0.5
AS-6	1988	**21.4	1.8 ± 0.3	4.2 ± 1.2	2.9 ± 0.4
AS-6	1989	2.3	2.1 ± 0.3	0.8 ± 1	<1.0
AS-6	1990	1.1	1.3 ± 0.1	1 ± 0.6	0.4 ± 0.3
AS-6	1991	0.6	0.9 ± 0.1	<0.04	0.9 ± 0.6
AS-6	1992	1.9	3.6 ± 0.1	9.2 ± 2.5	0.9 ± 0.4
AS-6	1993	0.7	0.8 ± 0.1	0.1 ± 0.1	0.2 ± 0.2
AS-6	1994	1.2	1 ± 0.1	5.2 ± 4.3	0.2 ± 0.2
AS-6	1995	1.5	1.4 ± 0.4	0.5 ± 0.4	1.5 ± 1
AS-6	1996	1.1	1.3 ± 0.2	0.7 ± 0.2	0.6 ± 0.3
AS-6	1997	1	1.2 ± 0.1	0.67 ± 0.11	1.1 ± 0.2
AS-6	1998	2.5	3.1 ± 0.2	2 ± 0.2	1.3 ± 0.2
AS-6	1999	3.5	**8.07 ± 0.3	**6.19 ± 0.49	**4.72 ± 0.28
AS-6	2000	1.1	0.99 ± 0.11	0.88 ± 0.18	1.12 ± 0.37
Mean		1.5	1.6	2.3	1.0
Std. Dev.		0.9	0.9	2.8	0.8
AS-5A	1988	0.9	2 ± 0.3	4.1 ± 1.2	1.3 ± 0.3
AS-5A	1989	2.1	2.4 ± 0.3	5.2 ± 1.2	<1.0
AS-5A	1990	1.1	0.9 ± 0.1	1.6 ± 0.6	0.2 ± 0.2
AS-5A	1991	6.5	1.1 ± 0.1	<0.04	0.5 ± 0.5
AS-5A	1992	0.5	2.5 ± 0.1	3.2 ± 1.4	1.1 ± 0.4
AS-5A	1993	0.5	1.4 ± 0.1	0.4 ± 0.2	0.7 ± 0.2
AS-5A	1994	1.4	1.6 ± 0.2	<0.02	0.5 ± 0.5
AS-5A	1995	1	1 ± 0.4	0.7 ± 0.5	1.7 ± 1
AS-5A	1996	1.4	1.2 ± 0.1	0.8 ± 0.1	0.7 ± 0.3
AS-5A	1997	2.1	1.4 ± 0.1	1.17 ± 0.15	1 ± 0.2
AS-5A	1998	2.7	1.4 ± 0.1	0.9 ± 0.1	1 ± 0.2
AS-5A	1999	2	1.46 ± 0.13	0.8 ± 0.11	0.79 ± 0.2
AS-5A	2000	2.7	1.54 ± 0.13	1.05 ± 0.16	0.92 ± 0.19
Mean		1.9	1.5	1.8	0.9
Std. Dev.		1.6	0.5	1.6	0.4

**Table 2-6 Post-Operation Soil Sample Results at Christensen Ranch Project**

Sample ID	Date	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
AS-5B	1988	1	1.6 ± 0.3	3.7 ± 1.1	1.5 ± 0.4
AS-5B	1989	1.3	1.7 ± 0.2	3.6 ± 1.2	1 ± 0.4
AS-5B	1990	0.9	1.4 ± 0.1	0.1 ± 0.1	1.8 ± 1.1
AS-5B	1991	9.2	0.6 ± 0.1	< 0.4	1.4 ± 0.6
AS-5B	1992	0.9	3.9 ± 0.1	5.1 ± 1.5	0.6 ± 0.4
AS-5B	1993	0.7	1.5 ± 0.1	0.7 ± 0.4	0.9 ± 0.2
AS-5B	1994	0.7	2.5 ± 0.2	< 0.02	0.8 ± 0.5
AS-5B	1995	0.9	1.3 ± 0.4	0.2 ± 0.3	1.5 ± 1
AS-5B	1996	1.1	1.3 ± 0.2	0.7 ± 0.1	1.1 ± 0.3
AS-5B	1997	0.8	1.2 ± 0.1	0.71 ± 0.12	< 0.05
AS-5B	1998	1.65	0.1 ± 1.3	1 ± 0.1	0.7 ± 0.2
AS-5B	1999	1.07	1.12 ± 0.11	0.57 ± 0.09	0.64 ± 0.19
AS-5B	2000	1.39	1.2 ± 0.12	0.83 ± 0.12	0.43 ± 0.18
Mean		1.7	1.5	1.6	1.0
Std. Dev.		2.3	0.9	1.7	0.4

AS-1, 6, 5A, & 5B

Mean	1.5	1.5	1.9	1.0
Std. Dev.	1.5	0.8	2.4	0.5

\*\* reported values considered outliers and not used in mean and standard deviation calculations

**Table 2-7 Summary of Soil Sample Results**

Site	Period	Uranium pCi/g	Ra-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
Irigaray Project*	Pre-Operations	0.5 ± 0.2	1.7 ± 0.7	3.2 ± 1.2	1.3 ± 0.7
Irigaray Project*	Post-Operations	1.0 ± 1.0	1.3 ± 0.8	1.7 ± 1.3	0.9 ± 0.5
Christensen Ranch Project	Pre-Operations	2.6 ± 1.5	2.6 ± 1.1	2.1 ± 1.6	1.7 ± 1.8
Christensen Ranch Project	Post-Operations	1.5 ± 1.5	1.5 ± 0.8	1.9 ± 2.4	1.0 ± 0.5
Mean		1.4	1.8	2.2	1.2

\* Reported standard deviation is standard deviation of the mean values at sampling points.

### Th-230 Background

The large variation in Th-230 concentrations may in part be due to biases in laboratory results. Due to this the variability, one cannot distinguish between sites or time periods. Therefore a mean value of 2.3 pCi/g is proposed as the mean concentration of Th-230, recognizing that a significant fraction of samples may exceed 4 pCi/g. The background for Th-230 is not anticipated to be relevant to the cleanup since available process water analyses indicate that Th-230 is not present in the water at significant levels. This is discussed further in Section 3.3. Therefore, further analyses for Th-230 in soil will not be made during the decommissioning or soil cleanup verification phase of the project.

### Ra-226 Background Concentration

As previously discussed, the pre-operations data for the Irigaray in Table 2-1 and consists of samples from 14 environmental monitoring stations (IR1 through IR15, excluding IR13), and five samples from the production units (P6 through P9). Even though there were only five samples from the production units, the Ra-226 concentrations ( $1.4 \pm 0.7$  pCi/g) compare well with those from the environmental monitoring stations ( $1.8 \pm 0.7$  pCi/g). The average Ra-226 of all locations is  $1.7 \pm 0.7$  pCi/g as presented in Table 2-7.

The post-operations data for the Irigaray Project given in Table 2-5 consists of samples from 18 environmental monitoring stations (IR1 through IR15, and the new IR1, 3 and 4), and 18 samples taken from the production units (Sample ID beginning with P or E). If the data are analyzed separately, the environmental monitoring station data result in a mean Ra-226 concentration of 1.2. The data for the production units result in a mean Ra-226 concentration of 1.5 pCi/g. Considering the variability, these results are in agreement. Therefore the mean value of 1.3 pCi/g appears reasonable from the post-operations data.

The pre-operations data set for the Christensen Ranch Project is the most complete data set of all with a mean and standard deviation of the Ra-226 concentration measurements of  $2.6 \pm 1.1$ . The post-operations data set for the Christensen Ranch Project consists of only the annual soil samples taken at the environmental sampling stations, which have a mean and standard deviation of  $1.5 \pm 0.8$  pCi/g for Ra-226.

Considering that the arithmetic mean for pre-operations and post-operations samples taken from both sites is 1.8 pCi/g and the very high variability, we propose a Ra-226 background for both sites of 2 pCi/g.

#### Natural Uranium Background Concentration

The only pre-operations uranium data that exist for the Irigaray Project is from the environmental monitoring stations. The mean and standard deviation of the 14 stations was  $0.5 \pm 0.2$  pCi/g. The post-operations data resulted in a mean and standard deviation of the uranium concentration of  $1.0 \pm 1.0$ . While the variability in the data would indicate agreement between the two sets of numbers, additional data suggest that a value of higher than 1 pCi/g is probably the real background. The data from the cleanup of the yellowcake spill area in 1995 consisted of 33 verification samples. After cleanups, most verification samples show little, if any, residual material and reflect background for the location. The analysis by Energy Laboratories, Inc. showed that the minimum uranium concentration value was 0.8 pCi/g with 14 values between 1.0 and 2.0 pCi/g. These data suggest a mean background value somewhere between 1 and 2 pCi/g.

The extensive pre-operations data at the Christensen Ranch Project resulted in a mean uranium concentration of 2.6 pCi/g. Post-operations data at the Christensen Ranch Project at the environmental monitoring stations showed that the average uranium concentration was 1.5 pCi/g. Considering the high variability in the data, we believe that a background uranium concentration of 2 pCi/g is appropriate for both sites.

### **3.0 Current Site Conditions**

Three sources of information exist regarding potential contamination at the site. The primary source of data is from documented spills of process water, pond leaks, and other liquids containing source or byproduct material already presented in Section 2.3. Measured radionuclide concentrations in the spilled water are useful in assessing the potential for contamination at the site. Environmental monitoring data are useful for determining if effluents have affected the general area of operations. This data has been evaluated in Section 2.4 and, with the exception of a station near the Irigaray Project Plant where a large yellowcake spill had occurred; the data indicate that the operations have had no measurable effect on the site. A third source of data is from radiological surveys and samples taken in known or suspected contaminated areas as well as data from wellfield process water. The results of this third source of data are discussed in Sections 3.2 and 3.3.

#### **3.1 Building Surface Contamination Survey and Exposure Rate Measurements**

A characterization survey was conducted in August 2000 by Environmental Restoration Group, Inc. (ERG). This information was necessary for developing a final verification plan for the buildings that may remain on site after decommissioning.

##### **3.1.1 Method and Equipment**

The equipment used to perform the building surface contamination is listed below.

- Ludlum Model 43-90, a 125-cm<sup>2</sup> large area alpha probe for total alpha contamination coupled to a Ludlum Model 2241 scaler/ratemeter.
- Ludlum Model 44-116, a 125-cm<sup>2</sup> large area beta probe for total beta contamination coupled to a Ludlum Model 2241 scaler/ratemeter.
- Ludlum Model 2929/43-10-1 alpha/beta tray counter for removable alpha and beta contamination.
- Ludlum Model 19 Micro-R survey meter to determine exposure rate.

The alpha and beta efficiencies were determined using National Institute of Standards and Technology (NIST) traceable sources. These sources were also used to function check the detectors prior to use. A Th-230 source was used for alpha and a Tc-99 source for beta. The model 19 Micro-

R Meter was factory calibrated and function checked using a Cs-137 source.

The building surface contamination survey consisted of measurements at eleven locations at the Irigaray Project and twenty locations at the Christensen Ranch Project. At each location a one-minute integrated count was taken with both the Ludlum Model 43-90 and 44-116 to determine total contamination levels. After the total contamination readings were taken, a swipe was taken over a 100-cm<sup>2</sup> area to determine removable contamination levels. At each location an exposure rate reading was also taken at contact. Locations were chosen so that the survey would cover all of the different areas of the buildings and in each area surveyed, the location was chosen by the physical appearance of potential contamination. Since the yellowcake drying and packaging area at Irigaray will be demolished, no measurements were made in this area.

The plastic scintillator used for detecting beta contamination is sensitive to gamma radiation. The gamma exposure rates within the process piping and tanks influenced the reported beta contamination levels. Therefore, beta contamination levels have not been included in this report nor used in developing this plan.

COGEMA personnel recently supplemented the data for the Irigaray plant by taking additional floor contamination measurements, using ZnS alpha detectors similar to those used in the survey by ERG. Twelve locations were selected for alpha measurements using COGEMA standard operating procedures. The locations were chosen in a similar manner as the ERG survey locations but they are not the same locations.

### **3.1.2 Results**

Table 3-1 includes the results of the contamination measurements made on the floor of the Irigaray and Christensen Ranch plants. The primary purpose of the data is to provide information on which to develop a MARSSIM-based final verification strategy. The data for the Irigaray plant collected by ERG personnel is given in the first three columns. The mean and standard deviation of the surface contamination levels are 2199 and 2335 dpm/100 cm<sup>2</sup>, respectively. A later survey was conducted by COGEMA using similar ZnS alpha detectors and COGEMA procedures. The

**Table 3-1 Total Alpha Surface Contamination in Plant Buildings**

Irigaray Project (ERG data) Gross Alpha (dpm/100 cm <sup>2</sup> )			Christensen Ranch Project (ERG data) Gross Alpha (dpm/100 cm <sup>2</sup> )			Irigaray Project (COGEMA data) Gross Alpha (dpm/100 cm <sup>2</sup> )		
Location No.*	Total	Removable	Location No.	Total	Removable	Location No.*	Total	Removable
1	8197	158	1	14	0	1	182	0
2	979	42	2	18	0	2	364	5
3	1883	0	3	4	0	3	454	3
4	1530	4	4	7	0	4	1273	0
5	738	33	5	14	4	5	2182	5
6	40	0	6	43	10	6	1818	3
7	3636	39	7	302	7	7	1909	0
8	760	0	8	248	81	8	1545	0
9	1879	0	9	1508	33	9	3636	5
10	2351	49	10	14	7	10	2000	0
			11	1516	4	11	1727	8
			12	119	13	12	2909	3
			13	2084	49			
			14	1087	30			
			15	716	7			
			16	781	0			
			17	29	4			
			18	25	10			
			19	40	23			
			20	0	20			
Mean	2199	14		429	15		1667	3
Std. Dev.	2335	25		638	20		1019	3

\* The measurement locations for the ERG and COGEMA surveys are different.

locations were different than those of the ERG survey. The last three columns in the table are results. The mean and standard deviation of the COGEMA measurements are 1667 and 1019 dpm/100 cm<sup>2</sup>, respectively, which agree well with the ERG measurements, considering that the measurement locations were different. Both sets of data show that the removable contamination at Irigaray is less than 5 percent of the total.

The data for the Christensen Ranch plant, taken by ERG personnel and presented in Table 3-1, indicate surface contamination levels slightly above 2,000 dpm/100 cm<sup>2</sup> but generally lower than in the Irigaray plant. The variability is similar to that measured at the Irigaray plant with a coefficient of variation of more than 100 percent.

### **3.2 Gamma Surveys and Soil Sampling**

Environmental Restoration Group, Inc. (ERG) conducted a surface soil characterization survey in August 2000. Gamma-ray levels and the concentration of radionuclides in soils were required to develop a gamma-ray action level. This action level will be used, in conjunction with soil sample results, to determine whether soil cleanup criteria are met. The surveys were conducted in areas of known large spills at the Irigaray and the Christensen Ranch Projects. Surveys were also done in areas where contamination was thought possible such as around well unit buildings, in certain drainages, around evaporation ponds, and at test site areas.

#### **3.2.1 GPS and Radiological Equipment**

A Ludlum Model 44-10 detector, 2-inch by 2-inch NaI detector, was coupled to a ratemeter/scaler and a Trimble ProXR GPS unit and used to automatically log individual gamma count rates and corresponding coordinates every two seconds. The GPS system was placed into a backpack worn by field personnel while walking at a rate of approximately 2.5 feet per second. The data were managed using the ArcView Geographic Information System (GIS) software program, a computer application for managing, displaying, and analyzing data geographically.

#### **3.2.2 Gamma Survey and Soil Sample Data Results**

The results of the GPS-based gamma surveys are shown in Figure 3-1 and Figure 3-2. Each color

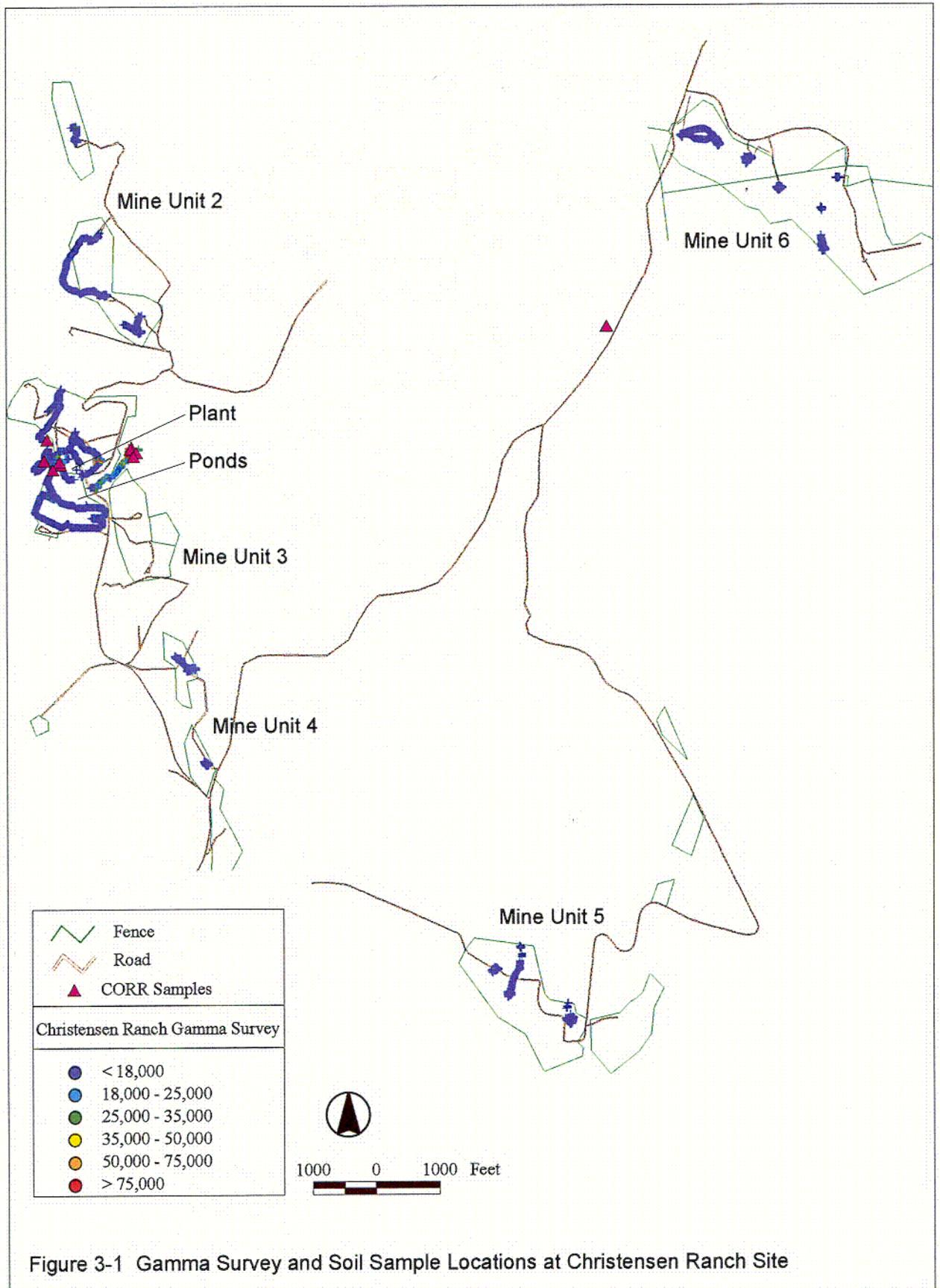
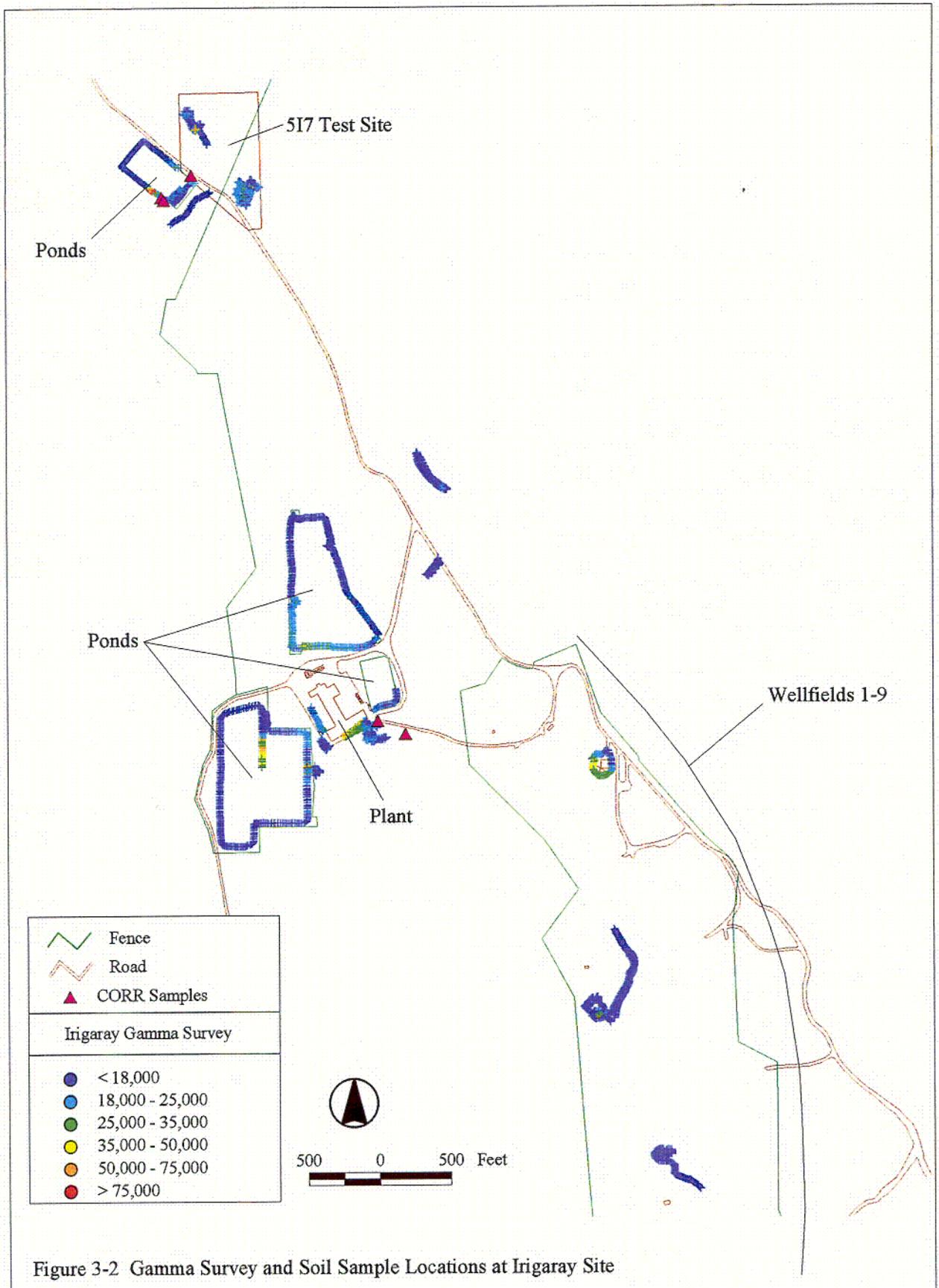


Figure 3-1 Gamma Survey and Soil Sample Locations at Christensen Ranch Site

c-1



C-2

dot in the figures represents a recorded count rate within one of the count-rate ranges given in the legend of the figure. Many of the areas that indicate high gamma levels are near pipes or other gamma-emitting sources. It is not, however, possible to eliminate the possibility that soil contamination exists in these areas without an extensive soil sampling effort or removal of the suspected source of gamma-ray emissions. These areas will require further investigation after the piping and other possible sources of gamma-shine are removed.

Because it was so difficult to find areas where the gamma levels indicated soil contamination, sampling points were often chosen based on potential contamination. After an area was chosen for sampling, it was scanned with the Ludlum Model 44-10, a 2-inch by 2-inch NaI detector, to locate a range of gamma readings from which to sample. At each sampling location, a one-minute count was taken with the 2-inch by 2-inch NaI detector at eighteen inches above the ground. An exposure rate measurement was then taken with the Ludlum Model 19 at one meter above the surface and at ground surface, and the coordinates were surveyed using the GPS unit. Lastly, a surface to 15-cm deep soil sample was taken.

Three samples were taken from around the Irigaray evaporation ponds, one sample was taken in an historic yellowcake spill area, and one sample was taken where runoff from the yellowcake spill area would have collected. At the Christensen Ranch Project, three samples were taken from around the evaporation ponds, two from the draw below the plant and evaporation ponds, four from an area of very high gamma readings where discharge water collected and left a chalky white material on the surface, and one background sample was taken away from mining operations.

The soil sampling locations in Figures 3-1 and 3-2 were the only locations where elevated gamma readings were found that could not be attributed to other sources such as gamma shine from piping, pumps, ponds, or other process systems. The samples were analyzed for uranium, Ra-226, Th-230, and Pb-210. Sample numbers beginning with IP and CR are from the Irigaray Project and Christensen Ranch Project, respectively. Data in Table 3-2 indicates that most of the results were near background levels, confirming previous findings that soils in the spill areas normally resulted in near-background concentrations of radionuclides. The results are discussed further in Section 7.

**Table 3-2 Gamma-Ray Count Rate, Exposure Rate, and Radionuclide Concentrations at Soil Sampling Locations**

Sample ID	Unshielded Model 44-10 @ 18" (cpm)	Model 19 @ Contact ( $\mu$ R/hr)	Model 19 @ 1m ( $\mu$ R/hr)	Pb-210 (pCi/g)	Ra-226 (pCi/g)	Th-230 (pCi/g)	Uranium (pCi/g)	Comments
IRCOR-01	23581	26	24	0.4	2.4	0.7	7.7	Near Irigaray evaporation ponds. Near a transfer line - shine is possible.
IRCOR-02	16683	18	18	0.4	1.2	0.5	1.3	Near Irigaray evaporation ponds.
IRCOR-03	17603	18	18	1.0	1.2	0.6	2.8	Near Irigaray evaporation ponds.
IRCOR-04	18730	22	19	13.7	1.2	0.9	537.0	Yellow cake spill low point at top of hill - hole material was 35 mR/hr.
IRCOR-05	15010	16	16	0.6	1.0	0.5	3.2	Bottom of hill where yellow cake spill would have collected.
CRCOR-01	18109	20	18	0.5	1.4	0.7	3.3	Near Christensen Ranch evaporation ponds.
CRCOR-02	24819	24	27	0.6	1.8	1.0	4.3	Near Christensen Ranch evaporation ponds.
CRCOR-03	15013	16	16	0.5	1.2	0.6	0.7	Near Christensen Ranch evaporation ponds.
CRCOR-04	16241	18	17	0.5	1.5	0.8	2.1	Draw below Christensen Ranch ponds.
CRCOR-05	16103	17	16	0.1	1.1	0.8	1.3	Draw below Christensen Ranch ponds.
CRCOR-06	13555	13	13	0.9	0.9	0.4	0.7	Background sample taken 25 feet off road with no mining in site.
CRCOR-07	23382	21	26	0.6	1.2	0.8	1.5	Discharge residuals (white crust). Possible shine.
CRCOR-08	63263	70	65	1.3	6.8	0.5	14.0	Discharge residuals (white crust). Possible shine.
CRCOR-09	46636	50	50	2.4	7.2	0.4	81.7	Discharge residuals (white crust). Possible shine.
CRCOR-10	29999	25	27	0.5	0.9	0.5	1.7	Discharge residuals (white crust). Possible shine.

\* IRCOR samples taken at Irigaray Site; CRCOR samples taken at Christensen Ranch Site

### 3.3 Process Water Radionuclide Content

Other than uranium, process water (lixiviant) was not normally analyzed for other radionuclides during mining. However, Ra-226 was analyzed in post-mining/pre-restoration composite samples from all five Mine Units (2,3,4,5&6) at Christensen and from Production Unit 6 at Irigaray. The mean Ra-226 concentration was 500 pCi/l with a range of 258-1020 pCi/l. Since uranium was the only radionuclide selectively removed from the lixiviant during mining, post-mining/pre-restoration concentrations of all other radionuclides should be near their maximum concentration.

The last two areas mined at the Christensen Ranch Project were Mine Units (MU) 5 and 6. A sampling of three wells from MU-6 was done in August 2000, representing the high, medium, and low concentrations of uranium in water. A composite sample of all active wells from MU-5 was also taken. Although these Mine Units were beginning the first phase of aquifer restoration (groundwater sweep), the samples should have radionuclide concentrations similar to the post-mining/pre-restoration samples. The results are presented in Table 3-3, which also include Pb-210 and Th-230. Note that the Pb-210 and Th-230 concentrations are very low and thus should not be radionuclides of concern.

**Table 3-3 Aquifer Restoration Water Radionuclide Content at the Christensen Ranch Project**

Sample I.D.	Pb-210 (pCi/l)	Ra-226 (pCi/l)	Th-230 (pCi/l)	U (mg/l)	U (pCi/l)
MU-6 Well 6AC66-3	146	380	2.0	22.5	15,200
MU-6 Well 6AO54-1	50.1	391	1.6	12.3	8,200
MU-6 Well 6AT58-2	19.1	112	<0.2	3.04	2,000
MU-5 Wellfield Recovery Composite	32.5	498	<0.2	0.552	370

Uranium production peaked in 1996, with an annual average grade of 56.7 mg/l U<sub>3</sub>O<sub>8</sub> for pregnant lixiviant at the Christensen Ranch Project. One can determine the maximum expected increase in the radionuclide concentrations from spills by assuming that the soil is saturated, and that the water is removed by evaporation rather than by draining (the predominant method for sandy soils). If one assumes a porosity of 0.4 and a dry density of 1.6 g/cm<sup>3</sup>, then 1 cm<sup>3</sup> of soil would contain 0.4 cm<sup>3</sup> of water, or 0.4cm<sup>3</sup> \* 1 liter/1,000 cm<sup>3</sup> \* 56.7 mg U/liter = .0227 mg U, or 15.35 pCi. Therefore (15.35 pCi/cm<sup>3</sup>)\*1cm<sup>3</sup> /1.6 g) = 9.6 pCi/g represents the maximum residual contamination from water containing 56.7 mg U/liter, assuming no ponding occurs. Ponding could increase the value somewhat, and could have occurred in some areas of the site since the soils are considered loam. However, most spills were not recoverable indicating ponding was not common. A similar calculation for Ra-226 using the maximum measured Ra-226 concentration of 1020 pCi/l would result in a concentration of less than 0.3 pCi/g of soil.

Since most of the spills had lower uranium concentrations and the rolling terrain in this area promotes runoff rather than ponding, it is not surprising that most of the measured uranium and radium levels are very low in the spill areas.

### **3.4 Studies to Reduce the Contamination Levels in Buried Pipes**

Alpha surveys were conducted on the interior of small sections of wellfield piping from five recovery wells and one recovery trunk line, to provide general contamination information. The piping was removed from restored or partially restored wellfields at both the Irigaray Project and Christensen Ranch Project and then cut open. Total alpha averaged 4,400 dpm/100 cm<sup>2</sup> (range 2,700 to 6,600).

Decontamination studies were conducted on the larger 4-inch recovery trunk line since their larger size provides the easiest and most accurate surveys. Surveys of four 10-inch long sections of the trunk line averaged 6,600 dpm/100 cm<sup>2</sup> (range 4,400 to 8,900). The sections were then soaked in a ten percent hydrochloric acid solution to determine if the contamination could be removed. After 30 minutes of soaking two sections were rinsed, dried and surveyed. The total alpha contamination dropped from 6,400 to 3,300 dpm/100 cm<sup>2</sup> on section # 1 and from 6,700 to 3,300 dpm/100 cm<sup>2</sup> on

section # 2. Removable alpha surveys swipes showed a reduction from 882 dpm/100 cm<sup>2</sup> to 519 dpm/100 cm<sup>2</sup>. Sections # 3 and #4 were soaked for 2 hours and then rinsed, dried and surveyed. The total alpha was reduced from 8,900 to 2,900 on section # 3 and from 4,400 to 1,300 on section # 4. Removable alpha survey swipes taken after the 2-hour soaking period showed 603 dpm/100 cm<sup>2</sup> levels for Section #3 and 627 dpm/100 cm<sup>2</sup> for section #4.

From this data it appears that wellfield piping can be decontaminated in place to levels below the release limits listed in Section 5.1 by flushing them with a hydrochloric acid solution. Although the contamination may exceed the ALARA goal in Section 5.1, the benefit of leaving the pipe in place far exceeds the cost of removal, shipment to Shirley Basin and disposal. Pipe flushing should be even more effective than soaking to remove interior contamination since more water movement and turbulence is created. If COGEMA decides to decontaminate interior piping with hydrochloric acid solutions, experiments will first be conducted to determine the most efficient and safest method. Waste solution will be placed in the evaporation ponds and ultimately be injected into a Class I injection well. Worksheet 6 of the updated bond lists a total of 694,700 linear feet of wellfield piping averaging 3 inches in outside diameter. This would be the amount most likely to be decontaminated by flushing .

### **3.5 Estimated Volume of Contaminated Soil**

The 2000-2001 Reclamation/Restoration Bond Estimate lists 507 cubic yards (13,700 cubic ft.) of soil which may be contaminated and removed from under the process areas at the Irigaray and Christensen sites. The estimate also lists 1,387 cubic yards (37,449 cubic feet) of the pond leak detection systems (gravel and pipe) which may be contaminated and removed. In addition it is assumed that 12 (5%) of the spill areas listed in Appendix A will have contaminated soil averaging 3 cubic yards, totaling 36 cubic yards.

## **4.0 Decommissioning**

Final decommissioning and demolition work will likely be performed by COGEMA personnel and outside contractor(s). In either case, the workers will receive industrial and radiation safety training according to the Section 8.2 of this plan. The radiation safety department will supervise decommissioning activities as described in Section 8.0. Section 5.0 lists the disposal options and survey requirements for decommissioned equipment, materials and structures. Those items that cannot be economically decontaminated below the releasable limits will be disposed of as outlined in Section 5.4. Other materials to be disposed of as byproduct material are process resins, sludge, and contaminated soils. Decommissioning procedures are given below for the three main areas: wellfields, process facilities, and waste ponds.

Groundwater restoration is beyond the intended scope of this decommissioning plan. The reader is referred to the January 1996 License Renewal Application (COGEMA, 1996).

## **4.1 Wellfields**

### **4.1.1 Well Plugging and Abandonment**

All wells will be plugged and abandoned in accordance with Section 6 of COGEMA, 1996. Wells include all injection and recovery wells, monitoring wells, and any other wells within the mine unit used for the collection of hydrologic or water quality data or incidental monitoring purposes. The only known exception at this time may be wells that could be transferred to the landowner for domestic or livestock use.

The objective of COGEMAS's well-abandonment program is to seal and abandon the wells in such a manner as to assure the groundwater supply is protected and to eliminate any potential physical hazard. The abandonment procedures contained herein are designed to comply with Wyoming Statute 35-11-404 and applicable regulations of the Department of Environmental Quality, Land and Water Quality Divisions and the Wyoming State Engineer's Office.

Two abandonment methods may be used as listed in Section 6 of the 1996 license renewal (COGEMA, 1996). The first method consists of using an acceptable bentonitic abandonment fluid

or cement to seal wells. The second method involves the placement of bentonite chips in the bottom 75 feet and upper 30 feet of the well with the intermediate volume filled with gravel. This method is currently used in the financial surety estimate for reclamation. For both methods, a cement cone is then placed two feet below the surface, surface casing is removed, and then the hole is backfilled.

A well abandonment report consistent with the requirements of Wyoming Statute 35-11-404 (e) will be filed with the Administrator of the Land Quality Division and the State Engineer's Office upon completion of the wellfield decommissioning.

#### **4.1.2 Trunk Lines, Pipes, and Wellfield Equipment**

Surface piping used for wellfield activities, such as injection and recovery well lines or trunk lines will be removed from the wellfields along with the meters and other related equipment. The underground piping (well lines and trunk lines) will either be excavated and removed, or surveyed to assure that they meet release criteria and left in place. If left in place, surveys will be conducted at all traps and other appropriate interior access points, provided that contamination at these locations is likely to be representative. If the residual contamination levels are above the release criteria the section of buried pipe will either be decontaminated in place or removed. As discussed in Section 3.4, decontamination of buried piping can be accomplished by soaking and/or flushing the pipe interior with a dilute hydrochloric acid solution. The pipe will first be isolated so that the solution cannot enter a well or spill onto the ground. Once the decontamination process is completed for sections of pipe, the pipe will be purged with air or water to ensure that it is emptied. The decontamination solution will either be stored in a tank for further use or disposed of in an evaporation pond.

While COGEMA believes that piping can be decontaminated to release limits in place, pipe buried less than two-feet deep will be removed to prevent it from being exposed by erosion or routine ranching activities. The removal of the piping is an ALARA initiative to minimize the potential for any human contact with the pipe. Buried piping should not result in any human radiation exposure since land-use options other than animal grazing are not anticipated for the decommissioned site.

Any process piping and related equipment removed from the wellfields will either be assumed to be contaminated and disposed of as byproduct material or will be released by one of the other disposal and release options given in Section 5.0.

## **4.2 Facilities**

### **4.2.1 Process Plants**

Small portable structures such as wellfield module buildings may be transported whole to any location, upon verification that the structures are releasable for unrestricted use. Releasable large structures with concrete foundations and sumps, such as the plant buildings, will either be decontaminated and left in place for the landowner or dismantled and transported in sections to an off-site location. Non-restricted area structures, such as the maintenance shop, warehouse, and/or office, may be left in place if desired by the landowner.

Standard building wrecking tools and methods will be used for removal of contaminated material and equipment from the process facilities as well as to demolish structures. Contaminated media will be removed from tanks and piping prior to removal and either processed or disposed of as byproduct material. The yellowcake dryer furnace poses the largest challenge as far as potential for worker exposure and environmental releases. Before decommissioning, the furnace's interior will be cleaned of the residual dried yellowcake, with the scrubber fan and scrubber operating. This will provide a negative pressure inside the furnace and limit yellowcake releases to the work area. If the unit is to be removed intact, the outlets and inlets will first be disconnected and capped. If the furnace is to be removed in sections, its interior will also be flushed with water to further reduce yellowcake emissions. Decommissioning and disposal options for the process buildings and equipment are given in Section 5.0.

### **4.2.2 Wellfield Buildings**

Most of the wellfield buildings are small enough to be transported intact and may be shipped to another licensee, or to an unrestricted location, if they can be decontaminated, to be released for unrestricted use. These small, industrial structures would not be suitable for long-term occupancy by workers or as a residence. Therefore, the decommissioning means for these structures will be

dependent upon which of the four disposal options listed in Section 5.0 is used.

#### **4.2.3 Laboratories**

Analytical laboratories exist at both the Irigaray and Christensen Ranch office facilities. Any remaining radioactive materials or samples in the labs will be removed and disposed of as byproduct material. Contamination surveys of the equipment, floors, walls, and counter surfaces of each laboratory will then be conducted. Special attention will be given to work areas used for weighing and analyzing concentrated uranium samples, and the ventilation systems in those areas. The lab sink(s) drain plumbing will be removed and either surveyed for release or disposed of as byproduct material. The lab sinks at both sites are not and have never been connected to the septic systems. These sinks drain into each respective plant waste sump which is pumped into the evaporation ponds.

COGEMA will either sell unused uncontaminated lab reagents or dispose of them through an EPA authorized disposal contractor.

#### **4.3 Evaporation Ponds**

Pond solutions will be disposed of by injection into the deep disposal wells pursuant to Wyoming DEQ UIC permits, or by treatment and discharge under existing NPDES permits and following NRC's criteria for liquid effluents released to unrestricted areas. Decommissioning Procedure D-1 (Evaporation Pond Decommissioning) provides guidelines for removal of pond water, sediment, liner and leak-detection piping. The sediment will be kept damp whenever it is handled to minimize airborne dust. Both hand labor and mobile equipment such as a backhoe or front-end loader will be used. The pond liner will then be cut into manageable sections and rolled or folded in a manner that minimizes the loss of any remaining sediments. Finally, the leak detection piping will be removed.

All pond sediments will be disposed of as byproduct material, along with any leak detection piping and liners not surveyed and released for unrestricted use. Surveying, sampling, and cleanup of the underlying and surrounding pond soils is addressed in Section 7.0 of this plan.

## **5.0 Disposal Options and Release Surveys**

The following sections address the four main disposal options to be used during decommissioning and the required radiation contamination surveys.

### **5.1 Equipment and Materials to be Released for Unrestricted Use**

Equipment and materials to be released for unrestricted use will be surveyed for radiation contamination as required by Condition 9.8 of Source Material License SUA-1341. Condition 9.8 references the NRC guidance document entitled "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated May 1987. Existing radiation safety SOPs will direct such surveys. Contamination surveys will be conducted on all equipment and materials located in restricted areas, in addition to any other potentially contaminated equipment and materials outside the restricted areas.

A reasonable effort will be made to eliminate residual contamination on potentially releasable equipment and materials. This will most often be accomplished by flushing or spraying with water. If decontamination is required to meet the releasable limits, other methods to be used include acid treatment and sandblasting. Decontamination residues will be properly handled and disposed of as byproduct material.

Objects with painted surfaces will not be released if it is known or suspected that paint had been applied over surface contamination. Both exterior and interior (where applicable) surfaces will be surveyed to detect potential contamination. Surfaces that are likely to be contaminated but are inaccessible for survey will be presumed to be contaminated above the limits and not released for unrestricted use.

The contamination on interior surfaces of piping and ducts will be determined by surveying at both ends and at all traps and other appropriate access points, provided that contamination at these locations is likely to be representative. Based on limited past experience, interior pipe contamination was found to be uniform with no evidence of buildup at connections, valves or other such or access

points. Most wellfield pipe is poly-plastic averaging 300 feet in length with only end connections. Plant piping is mostly iron and PVC plastic, which has connections spaced at 20 feet or less.

An ALARA goal of 1,000 DPM/100 cm<sup>2</sup> total alpha, will be applied during decommissioning. However, the limits given below will be used if a reasonable effort has been made to eliminate residual contamination as stated in this section.

The releasable limits as per the NRC guidance document (May 87) and Regulatory Guide 1.86, are summarized as follows:

Alpha: Removable of 1,000 DPM/100 cm<sup>2</sup>.

Average total of 5,000 DPM/100 cm<sup>2</sup> over an area no greater than 1 square meter.

Maximum total of 15,000 DPM/100 cm<sup>2</sup> over an area no greater than 100 cm<sup>2</sup>.

The monitoring for beta-gamma dose rate is a current license requirement, based on the referenced 1987 NRC guidance document. This requirement has been eliminated in subsequent ANSI standards, including the latest ANSI/HPS N13.12-1999 standard, "Surface and Volume Radioactivity Standards for Clearance." COGEMA has routinely made these measurements but has never found them limiting. The process characterization data indicate that the alpha emitting radionuclides, uranium and Ra-226, are the principal radionuclides in the process water and thus are the principal constituents in contaminated areas. The measurement methods and associated performance capabilities of existing instrumentation for alpha-emitting radionuclides has been shown (see Appendix C) to be very adequate to detect alpha contamination at a small fraction of the regulatory limits. Therefore, COGEMA proposes to make only alpha surface contamination measurements on equipment and materials to be released for unrestricted use during decommissioning.

Equipment and materials released for unrestricted use will either be placed in an approved landfill, or salvaged.

## **5.2 Buildings to be Released for Unrestricted Use**

Structures that are in a restricted area or have been used for process purposes outside a restricted area will either be released for unrestricted use (after surveys and appropriate decontamination), or disposed of by one of the methods discussed in Sections 5.3 and 5.4 below. COGEMA will decide on the fate of each building based upon radiological survey results, interest of other licensees in such structures (for transport to their sites), or the interests of other parties in releasable structures. Buildings to be released for unrestricted use will first have all process equipment and piping removed. A survey of all the structures interior surfaces will then be conducted using the methods and procedures discussed in Appendix C. The exterior surfaces at vent and stack locations will also be surveyed for contamination. If the releasable levels cannot be achieved in portions of the structure, they may be removed and disposed of as byproduct material.

Small portable structures such as wellfield module buildings may be transported whole to any location, upon verification that the structures are releasable for unrestricted use. Releasable large structures with concrete foundations and sumps, such as the plant buildings, will either be left in place for the landowner or dismantled and transported in sections to an off-site location. Because of the young age of the Christensen Ranch Project plant and the excellent condition of the underlying concrete, no contamination of the soil under the concrete should exist. Therefore, if the landowner so desires, that building should be releasable in place, subject to the survey of the superstructure. In the case of the Irigaray Project plant facility, contamination of the soil underlying the foundation is expected. The sumps at Irigaray may have been subject to some leakage in the past, and the documented spills (most notably the yellowcake slurry spill from the capsized tank in 1994) increase the likelihood of contamination beneath the foundation. Consequently, the yellowcake storage and handling areas and most of the rest of the facility (superstructure) that functioned as a restricted area will be subject to removal (either for release to unrestricted use elsewhere or for disposal as byproduct material, depending upon survey results and decontamination efforts). The adjacent non-restricted area structures, such as the maintenance shop, warehouse, and/or office, may be left in place if so desired by the landowner. In such cases, the removal of the process building will allow access to the immediately adjacent soil below the foundations of the structures to be left intact. Soil sampling will be conducted to confirm that there was no migration of contamination underneath the

unrestricted building(s). Soil sampling and analysis are discussed in Section 7.0.

The Irigaray restricted-area building foundation and floor concrete, where contaminated, will be either removed for disposal as byproduct material, or it will be decontaminated prior to disposal at a conventional landfill site or within the evaporation pond excavation after liner removal and verification.

### **5.3 Contaminated Equipment, Materials, and Buildings Transferred to Another Licensee**

Salvageable contaminated equipment such as tanks, pumps, reverse osmosis filtration units, along with small movable structures such as wellfield module buildings, may be transferred to another licensed facility. If the surface contamination exceeds the limits for unrestricted use, the equipment or structures will be shipped to the licensed facility as per DOT regulations 49 CFR. SOP HP-25, Transferring Contaminated Equipment or Materials Between NRC Licensees, outlines the regulations and procedures for such transfers. In most cases the equipment or structures will be shipped as Surface Contaminated Object (SCO-I), DOT regulations 49 CFR 173.427, UN2913, or as Empty Packages as Excepted Packages, DOT regulations 49 CFR 173.428, UN 2910

Equipment and structures will be free of any loose exterior contamination and drained of any process liquids prior to shipment. When tanks are shipped as an empty package, all bottom pipe connections or drains will be sealed. If necessary the equipment or structure will be washed to insure that the exterior contamination is not easily removable. External exposure and contamination surveys will be conducted and documented to insure the DOT limits in 49 CFR 173.427 (a) (1), 173.441 and 173.443 are met. Surface contaminated objects (SCO-1) will be transported as an exclusive use shipment in a strong tight container that prevents leakage of the radioactive contents under normal conditions of transport, as specified in 173.427(b) (3).

### **5.4 Contaminated Equipment, Materials, and Buildings Disposed of as Byproduct Material**

Byproduct material includes equipment, materials and dismantled structure sections not covered by Section 5.3 and which cannot be economically decontaminated below the releasable limits. Also categorized as byproduct material are process resins, sludges, and contaminated soils. Byproduct

shipments will be sent to an NRC licensed facility for disposal (currently to Pathfinder Mines Corporation, Shirley Basin tailings facility). Appendix 2 of COGEMA, 2000 includes a copy of the Byproduct Materials Disposal Agreement with Pathfinder, which provides details of the acceptable materials and other requirements. Shipments will be conducted as per SOP HP-20, Procedure for Shipping Byproduct Material to Pathfinder's Shirley Basin Tailings Facility. In most cases the byproduct material will be shipped as Low Specific Activity (LSA-I) material, pursuant to DOT regulations at 49 CFR 173.427, UN2912.

External exposure and contamination surveys will be conducted and documented to insure the DOT limits in 49 CFR 173.427 (a) (1), 173.441 and 173.443 are met. Byproduct will be transported as an exclusive use shipment in a strong tight container that prevents leakage of the radioactive contents under normal conditions of transport, as specified in 173.427(b) (3).

## **6.0 Derived Decontamination Limits and Verification Plan for Buildings**

### **6.1 Derived Decontamination Limits for Facilities**

RESRAD-Build 3.0 was used to evaluate the dose to industrial workers occupying the buildings formerly used for extracting uranium at the ISL sites. The use for these buildings, if left at the site, is most likely to be storage and maintenance of ranching or farm equipment. Another possible use of the plant buildings would be as a service center for the local oil and gas industry.

The most restrictive exposure scenario related to these buildings is for workers, probably mechanics, hired to service equipment brought to the site. The current offices or portions of the offices associated with the plant buildings are uncontaminated and assumed to remain to serve as administrative and support facilities for the workers. Therefore the workers would normally take breaks and eat lunch in the currently uncontaminated office facilities.

The surface contamination should reflect the principal constituents in the process water at the plants as discussed in Section 3.4, namely uranium, radium-226, and lead-210. The approach used was to calculate the radiological dose to industrial workers, assuming that the surface contamination was made up exclusively of one of the constituents. As will be seen, the worst-case model assumed all of the contamination to be uranium. The total gross alpha surface contamination limit was then based on the presence of uranium that would result in a maximum dose to the workers of 25 mrem/y, according to the dose criterion in 10 CFR Part 20, §20.1402. By choosing this approach, the gross alpha contamination limit eliminates the need to determine the radionuclide mix within the structures.

The modeling of the buildings using RESRAD-Build is included in Appendix B. It is shown that a gross alpha contamination limit, averaged over the 100-m<sup>2</sup> floor, will limit the annual dose to a worker to 25 mrem. Since the principal dose pathway is via inhalation, no maximum contamination limit is appropriate.

### **6.2 Characterization and Verification Plan for Buildings**

A building characterization and surface contamination verification plan has been developed for any

buildings to remain on site. NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), was used as the principal guidance document in developing the plan. The details of the plan are included in Appendix C. The plan incorporates the ALARA concept by assuring that small areas having gross alpha contamination at a fraction of the 1,000-dpm/100 cm<sup>2</sup> criterion are identified. Further efforts at decontaminating these areas are required prior to applying the final verification procedure. In order to assure that alpha emissions are not attenuated, beta measurements will be made during the decontamination phase as well as in the final verification step.

## **7.0 Cleanup of Surface and Subsurface Soils**

The cleanup of surface and subsurface soils will be done according to the requirements in 10 CFR Part 40, Appendix A. Appendix A indicates that the Ra-226 concentration in soil should be limited to 5 pCi/g above background for 15-cm thick surface layers, averaged over 100 m<sup>2</sup>. Similar layers of subsurface contamination are limited to 15 pCi/g.

The NRC amended 10 CFR Part 40 on April 12, 1999 (FR/Vol. 64, No. 69, pp17506-17509) to require uranium recovery licensees to consider radionuclides other than Ra-226 in soil cleanup criteria. The existing soil Ra-226 criterion in 10 CFR Part 40, Appendix A, is used to derive a dose criterion (Benchmark Approach) for the cleanup of byproduct material radionuclides, including Ra-226. The radionuclide-specific criteria are adjusted so that the total dose resulting from the mixture of residual radionuclides will not exceed the Benchmark Dose. The dose from radon is excluded from the benchmark calculation. Other recommended guidance documents that were reviewed include NUREG-1620 and NUREG-1549.

The only radionuclides other than Ra-226 of concern at the Irigaray Project and Christensen Ranch Project are from natural uranium, a mixture of U-238, U-234, and U-235. The activity percentages for these radionuclides are approximately 0.489, 0.489, and 0.022, respectively.

### **7.1 Cleanup Limits for Soils**

The Benchmark Dose was modeled (see Appendix D) using the RESRAD and DANDD codes. The results show that a concentration of 400 pCi/g for natural uranium is equivalent to the Benchmark Dose derived from a concentration of 5 pCi/g of Ra-226. It can conservatively be assumed, from a radiological exposure perspective, that since the subsurface concentration limit for Ra-226 is 15 pCi/g, then the subsurface concentration limit for uranium would be 1200 pCi/g. It will be shown below that the uranium concentration should be limited to 600 pCi/g for all soil depths because of chemical toxicity concerns. This would then result in a maximum surface contamination limit for uranium of 400 pCi/g in the surface 15-cm layer and 600 in the subsurface layer.

ALARA considerations require that an effort be made to reduce contaminants to as low as

reasonably achievable levels. The ALARA goals are normally based on a cost-benefit analysis. For the cleanup of gamma-emitting radionuclides, the cost of cleanup becomes excessively high as the soil concentrations become either indistinguishable from background or the gamma emission rate corresponding to a soil concentration becomes indistinguishable from the gamma background count-rate. For uranium, the concentrations corresponding to these two situations are quite different.

COGEMA (Pathfinder Mines Corp.) demonstrated in the cleanup of two uranium mill sites that the use of a conservatively derived gamma action level, along with procedures similar to those in this plan, results in near background Ra-226 concentrations for the site. It is therefore believed that no specific ALARA goal is required for surface Ra-226. The proposed gamma action level (See Section 7.2.1) has been established at near background levels and is considered adequate to limit the concentration of Ra-226 to 5 pCi/g above background levels. The presence of a mixture of Ra-226 and uranium will tend to drive the cleanup to even lower Ra-226 concentrations.

Establishing an ALARA goal for uranium is more difficult. The calculated dose rates from the direct exposure to uranium and Ra-226 in soils are available from the RESRAD runs in Appendix D. The ratio of the Ra-226 dose rate per pCi/g to the uranium dose rate per pCi/g is 128. In this analysis, it is assumed that the dose rate for direct exposure is proportional to the average photon energy times the emission rate, or

$$D = k E R$$

where

- k is the proportionality constant,
- D is the direct dose rate,
- E is the average photon energy, and
- R is the emission rate.

Writing an equation for pure uranium and one for Ra-226 plus progeny, and dividing results in the following equation:

$$R_{\text{Ra}}/R_{\text{U}} = (D_{\text{Ra}} \cdot E_{\text{U}}) / (D_{\text{U}} \cdot E_{\text{Ra}})$$

The average gamma energy from uranium is approximately 100 keV and the average energy from Ra-226 plus progeny is on the order of 400 keV. Substituting  $D_{\text{Ra}}/D_{\text{U}} = 128$  and  $E_{\text{U}}/E_{\text{Ra}} = 100/400$ , then  $R_{\text{Ra}}/R_{\text{U}} \approx 30$ .

For a gross-gamma count rate meter in the field, the count rates are proportional to the emission rate ratios, adjusted for the detection efficiency differences for the two different spectra. Assuming that the difference is small, the ratio of the count rates should be about 30. Therefore if the action level for pure Ra-226 results in cleanup of the site to less than 5 pCi/g, the action level should result in the cleanup of pure uranium to  $30 \cdot 5$ , or 150 pCi/g. When both radionuclides are present, the levels should be somewhat lower. Based on the above argument, COGEMA proposes an ALARA goal of limiting the uranium concentration in the top 15-cm layer to 150 pCi/g, averaged over an area of 100 m<sup>2</sup>.

Subsurface contamination will more than likely be found beneath the process portion of the Irigaray Plant, possibly beneath evaporation pond liners, and possibly in pipe trenches. The difficulty in monitoring for removal is seldom as favorable under these conditions as for surface contamination. It is COGEMA's desire to reduce the subsurface concentrations to a maximum of two-thirds of the proposed limits of 15 pCi/g above background for Ra-226 and 600 pCi/g for uranium. Therefore ALARA goals for Ra-226 of 10 pCi/g above background and for uranium of 400 pCi/g are proposed. It should be recognized that unforeseen circumstances, such as contamination extending to great depths, could result in the cost overriding the benefit of attempting to reach an ALARA goal. Should this happen, COGEMA will document why the ALARA goal was knowingly abandoned. It should also be recognized that backfilling may be required (for safety reasons) prior to receiving the confirmation sample laboratory results. In some situations, sample results may surprisingly be higher than the ALARA goals. The cost/benefit ratio for remediating backfilled areas to meet ALARA goals will normally be prohibitively high.

### Chemical Toxicity Assessment

The chemical toxicity effects from uranium exposure are evaluated by assuming the same exposure scenario as that used for the radiation dose assessment. In the Benchmark Dose assessment for the resident scenario, it was assumed that the diet consisted of ten percent of the fruits and vegetables grown at the site. No intake of contaminated food through the aquatic, milk, or meat pathways was considered probable. Also, the model showed that the contamination would not affect the groundwater quality. Therefore, the same model will be used in assessing the chemical toxicity.

The method and parameters for estimating the human intake of uranium from ingestion are taken from NUREG/CR-5512 PNL-7994 Vol. 1 (October 1992). The uptake of uranium in food is a product of the uranium concentration in soil and the soil-to-plant conversion factor. The annual intake in humans is then calculated by multiplying the annual consumption by the uranium concentration in the food. Since the soil-plant conversion factor is based on a dry weight, the annual consumption must be adjusted to a dry-weight basis by multiplying by the dry-weight to wet-weight ratio. Parameters for these calculations are given in Section 6.5.9 of the NUREG/CR-5512. Table 7-1 provides the parameters used in these calculation and results for leafy vegetables, other vegetables, and fruit. It is assumed that a garden or orchard has a uranium concentration in soil of 400-pCi/g. This corresponds to the uranium Benchmark Concentration for surface soils. Using a conversion factor for natural uranium of 1 mg = 677 pCi, then 400 pCi/g is equivalent to 591 mg/kg. The human intake shown in Column No. 1 of Table 7-1 is equal to the product of the parameters given in the subsequent columns. Table 7-1 shows that the total annual uranium intake from all sources of food from the site is 14.7 mg/year.

The ICRP69 (International Commission on Radiological Protection, 1995) two-compartment model of uranium toxicity in the kidney from oral ingestion was used to predict the burden of uranium in the kidney following chronic uranium ingestion. This model allows for the distribution of the two forms of uranium in the blood, and consists of a kidney with two compartments, as well as several other compartments for uranium distribution, storage and elimination including the skeleton, liver, red blood cells (macrophages) and other soft tissues.

Table 7-1 Annual Intake of Uranium from Ingestion

Human Intake (mg/y)	Soil Concentration (mg/kg)	Soil-to-Plant (mg/kg plant to mg/kg soil)	Annual Consumption (kg)	dry wt/wet wt	Food Source
2.21	591	1.7E-2	1.1	0.2	Leafy Vegetables
10.5	591	1.4E-2	5.1	0.25	Other Vegetables
1.96	591	4.0E-3	4.6	0.18	Fruit
14.7					Total

The total burden to the kidney is the sum of the two compartments. The mathematical representation for the kidney burden of uranium at steady state can be derived as follows:

$$Q_p = \frac{IR f_1}{\lambda_p (1 - f_{ps} - f_{pr} - f_{pl} - f_{pt} - f_{pk1})} \quad 5)$$

where:

- $Q_p$  = uranium burden in the plasma,  $\mu\text{g}$ ;
- $IR$  = dietary consumption rate, mg U/d;
- $f_1$  = fractional transfer of uranium from GI tract to blood, unitless;
- $f_{ps}$  = fractional transfer of uranium from plasma to skeleton, unitless;
- $f_{pr}$  = fractional transfer of uranium from plasma to red blood cells, unitless;
- $f_{pl}$  = fractional transfer of uranium from plasma to liver, unitless;
- $f_{pt}$  = fractional transfer of uranium from plasma to soft tissue, unitless;
- $f_{pk1}$  = fractional transfer of uranium from plasma to kidney compartment 1, unitless;
- $\lambda_p$  = biological retention constant in the plasma,  $\text{d}^{-1}$ .

The burden in kidney compartment 1 is:

$$Q_{k1} = \lambda_p Q_p \frac{f_{pk1}}{\lambda_{k1}}$$

**where:**

- $Q_{k1}$  = uranium burden in kidney compartment 1, mg;  
 $\lambda_{k1}$  = biological retention constant of uranium in kidney compartment 1, d<sup>-1</sup>.

Similarly, for compartment 2 in the kidney, the burden is:

$$Q_{k2} = \lambda_p Q_p \frac{f_{pk2}}{\lambda_{k2}}$$

where:

- $Q_{k2}$  = uranium burden in kidney compartment 2, µg;  
 $\lambda_{k2}$  = biological retention constant of uranium in kidney compartment 2, d<sup>-1</sup>;  
 $f_{pk2}$  = fractional transfer of uranium from plasma to kidney compartment 2, unitless.

The total burden to the kidney is then the sum of the two compartments

$$Q_{k1} + Q_{k2} = \frac{IR f_1}{(1 - f_{ps} - f_{pr} - f_{pl} - f_{pt} - f_{pk1})} \left[ \frac{f_{pk1}}{\lambda_{k1}} + \frac{f_{pk2}}{\lambda_{k2}} \right]$$

The parameter input values for the two-compartment kidney model include the daily intake of uranium estimated for residents at this site, and the ICRP69 values recommended by the ICRP as listed below (ICRP, 1995). The daily uranium intake rate was estimated to be 0.040 mg/day (14.7 mg/year) from ingestion while residing at this site.

- |          |   |              |                |   |             |
|----------|---|--------------|----------------|---|-------------|
| $IR$     | = | 0.040 mg/day | $f_{pk1}$      | = | 0.00035     |
| $f_1$    | = | 0.02         | $f_{pk2}$      | = | 0.084       |
| $f_{ps}$ | = | 0.105        | $\lambda_{k1}$ | = | ln(2)/5 yrs |

$$\begin{array}{ll}
 f_{pr} & = & 0.007 & \lambda_{k2} & = & \ln(2)/7 \text{ days} \\
 f_{pl} & = & 0.0105 & \text{where } \ln(2) & = & 0.693\dots \\
 f_{pt} & = & 0.347 & & & 
 \end{array}$$

Given a daily uranium intake of 0.040 mg/day at this site and the above equation, the calculated concentration of uranium in the kidney is 0.009  $\mu\text{g U/g}$ . This is approximately one percent of the 1.0  $\mu\text{g U/g}$  value that has generally been assumed to protect the kidney from the toxic effects of uranium. Some researchers have suggested that mild effects may be observable at levels as low as 0.1  $\mu\text{g U/g}$  of kidney tissue. Using 0.1  $\mu\text{g U/g}$  as a criterion, then the intake is nine percent of the considered safe level.

The EPA recently evaluated the chemical toxicity data and found that mild proteinuria has been observed at drinking water levels between 20 and 100  $\mu\text{g/liter}$ . Assuming water intake of 2 liters/day, this corresponds to an intake of 0.04 to 0.2 mg/day. Using animal data and a conservatism factor of 100, the EPA arrived at a 30  $\mu\text{g/liter}$  recommended limit for use as a National Primary Drinking Water Standard (Federal Register/Vol.65, No.236/ December 7, 2000). This is equivalent to 0.06 mg/day for the average individual. Naturally, since large diverse populations are potentially exposed to drinking water sources regulated using these standards, the EPA is very conservative in developing limits.

This analysis indicates that a soil limit of 400 pCi/g of U-nat would result in an intake of 0.04 mg/day. A soil limit of 600 would correspond to the EPA intake limit from drinking water of 0.06 mg/day. Therefore this intake should not result in chemical toxicity effects. Since the roots of a fruit tree would penetrate to a considerable depth, limiting subsurface uranium concentrations to 600 pCi/g will be considered appropriate as well.

## 7.2 Soil Cleanup and Verification

The soil cleanup and verification process is based on procedures that, when used collectively, provide a high degree of assurance that contaminated areas are found and successfully remediated. Gamma surveys will be used to guide the soil remediation efforts. The surveys will identify

potential soil contamination that exceeds the cleanup criteria and are also used to guide the cleanup efforts. After cleanup, the surveys will be used, in conjunction with surface soil sample analyses, to verify cleanup to the site cleanup criteria.

A gamma action level, defined as a gamma count-rate level corresponding to the soil cleanup criterion, is used in the interpretation of the data. Normally the action level is conservatively developed to allow only a five percent error rate of exceeding the cleanup criteria at the 95% confidence level. It will be shown (Section 7.2.1) that at these sites, inadequate data exist to determine an action level as defined above. Instead, it was necessary to define the gamma action level as an investigation level where the concentration of gamma-emitting radionuclides may be above the variation in natural background concentrations.

The gamma characterization survey (section 7.2.2), excavation control monitoring (Section 7.2.3), and the Verification Survey (Section 7.2.4) are considered collectively when assessing the adequacy of the GPS-based verification gamma survey and soil sampling method. In the initial characterization survey, the data density is similar to that in the final survey. Prior to accepting the surveys, the data maps are reviewed to assure that the data are uniformly distributed. Areas with missing data are investigated and either resurveyed or an explanation is presented in the report as to why the data could not be obtained.

Areas represented by data points in the characterization survey that exceed the gamma action level are investigated and the area remediated. Excavation control monitoring during soil removal is done to assure that contaminated soils are removed and that residual levels are below the gamma action level. The affected area is surveyed again as a part of the verification survey.

In the final verification survey, a minimum of seven data points is proposed to assure that there are no 100-m<sup>2</sup> grid blocks with data missing from significant portions of the grid blocks. The identification of the grid blocks and the counting of data records are done by computer, as described in SOP D-3. Since contaminated areas have already been remediated and excavation control monitoring indicates areas are below the action level, the final gamma data should be uniformly low

and near background levels. The only alternative to reducing grid blocks to below the gamma action level is to verify that the grid block meets the cleanup criteria by soil sampling and analysis.

The sampling program detailed in SOP D-3 provides an added level of assurance that the gamma action level conservatively predicts that an area meets the cleanup criteria. The average count rate for the 100-m<sup>2</sup> grid blocks within the two areas of each site is calculated. The grid blocks are ranked according to the average count rate and the top ten percent of the grid blocks are sampled according to the procedure. If any of these grid blocks fail verification by soil sampling and analysis, the second ten percent of the grid blocks are sampled, and so on. A final statistical test is done to assure that the mean of the sample results, at the 95 percent confidence level, is below the cleanup criteria.

#### **7.2.1 Gamma Action Level**

The gamma action level is determined from data taken on a known contaminated site, using equipment and methods similar to those that will be used during the soil cleanup verification phase of decommissioning. Verification plans call for sampling all 100-m<sup>2</sup> grid blocks that exceed the gamma action level using a five-point composite sampling procedure. A percentage of the grid blocks with gamma count rates below the action level are also sampled. The percentage depends upon the accuracy of the action level and site conditions.

The results of the preliminary site characterization described in Section 3 were used to develop the action level. The gamma survey revealed that very few areas were discovered where gamma levels and soil contamination exist at significant levels. Most of the elevated gamma readings could be attributed to contaminated piping, evaporation ponds, or process vessels. It will be shown that paucity of data does not allow a rigorous statistical approach to developing an action level. Instead, a more qualitative approach has been used, making use of the few data points available at this time.

As a part of the preliminary characterization, data to develop a correlation were obtained by taking gamma count rate levels at the soil sampling location. An extensive effort at locating additional sampling points was made but, at this time, additional potentially contaminated areas are not evident.

Since the contaminated areas were small and the aerial distribution non-uniform, no attempt was made to determine the average count rate and average radionuclide concentration in a 100-m<sup>2</sup> grid block. Instead, the gamma count rate was measured above the soil-sampling location at an 18-inch height above the soil surface. This detector height will be used in the final verification survey. A correlation using the averages (Ra-226 concentration and gamma count rate) has been shown to agree with a correlation developed by point measurements (PMC, 1997).

Table 3-2 in Section 3 provides a summary of the data taken for the purposes of developing an action level along with additional information. The exact sampling locations have been provided in Figures 3-1 and 3-2. Of the 15 sampling points, only sample CRCOR-06 was known to be a background sample. This sample was taken from an area away from the plant or ore trends and was clearly considered unaffected, as indicated by the very low count rate of 13,555 cpm. The radionuclide concentrations for that sample were within the range of values considered background for the site. Section 3.2 presents the background data and proposes natural background values of 2 pCi/g for both uranium and Ra-226 in surface soils for both sites. The data are quite variable with the upper range of values known to exceed 4 pCi/g in some locations.

Sample IRCOR-04 was taken from the yellowcake spill area with a uranium concentration of 537 pCi/g and radium-226 concentration of 1.2 pCi/g. Yellowcake was evident at a depth of 3-6 inches where this sample was taken, indicating residuals from the spill were in the sample. Since the yellowcake was highly concentrated in a small area, this sample result is not useful for developing an action level. However, the Pb-210 and Th-230 content of this sample, along with the results for all the other samples, indicate that these radionuclides do not need to be considered further in yellowcake-affected areas. The near-background Ra-226 concentration also shows that the purified uranium product does not contain Ra-226.

Only one other sample showed highly elevated uranium but low Ra-226 concentration. This sample, CRCOR-09 was taken near the NPDES discharge point and had a uranium concentration of 81.7 pCi/g and a Ra-226 concentration of 7.2 pCi/g. All samples showed near background levels for Th-230. None of these samples were taken from the surface of the mineralized portion of the site,

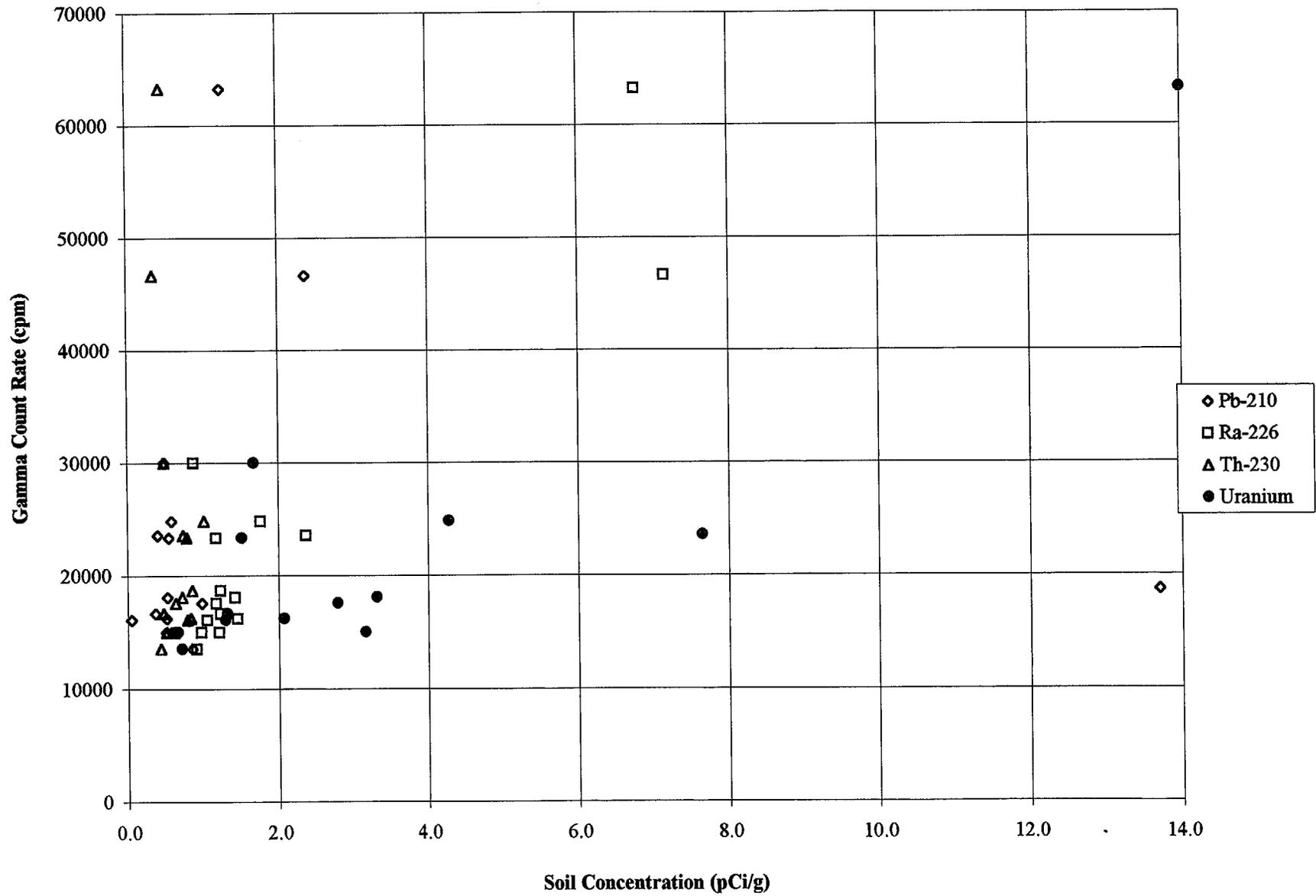
namely the wellfield areas (production unit or mine unit areas).

Figure 7-1 shows a plot of the radionuclides of interest plotted against the gamma count rate using the data in Table 3-2. The values for uranium from sample CRCOR-09 and IRCOR-04 have been omitted in order to view the lower activity samples. The Th-230 and Pb-210 in the samples would not expect to correlate with the gamma-count rate. The plot emphasizes the fact that the concentrations are very low in all samples and thus the Th-230 and Pb-210 constituents are not of importance in the soil cleanup.

In order to obtain a better understanding of the gamma correlation, Figure 7-2 shows the same data for the Ra-226 correlation. As anticipated, the gamma count rate is primarily dependent upon the Ra-226 concentration and to a much lesser extent, the uranium concentration. The Ra-226 correlation is very similar to that found at the Pathfinder Mines Corporation's Lucky Mc and Shirley Basin Mill sites in Wyoming, where the influence of uranium was very small. Figure 7-3 is a plot of the uranium concentration and gamma count rate. It clearly demonstrates that the uranium concentration has a small effect on the gamma count rate compared to Ra-226. The linear regression line has been shown but it clearly demonstrates why the linear regression technique is not recommended for such data frequency distributions.

While most of the Ra-226 values are near background with corresponding uranium values near background, the correlations suggest that a count rate of less than 30,000 cpm would conservatively predict that the Ra-226 concentrations were below the upper range of natural background (approximately 4 pCi/g). In Figure 7-1, two uranium values are shown between 4 and 8 pCi/g whose Ra-226 concentrations (1.8 and 2.4 pCi/g) are near the average background concentrations for the sites. These two data points suggest that a gamma count rate of 25,000 cpm or less should indicate that the uranium concentration is no higher than 8 pCi/g. While the supporting data are weak at this time, we propose to use an action level of 25,000 cpm as an action level and continue to build the database during cleanup.

A correlation between the Ludlum Model 19 Micro-R meter and the Ludlum 2221/Ludlum 44-10



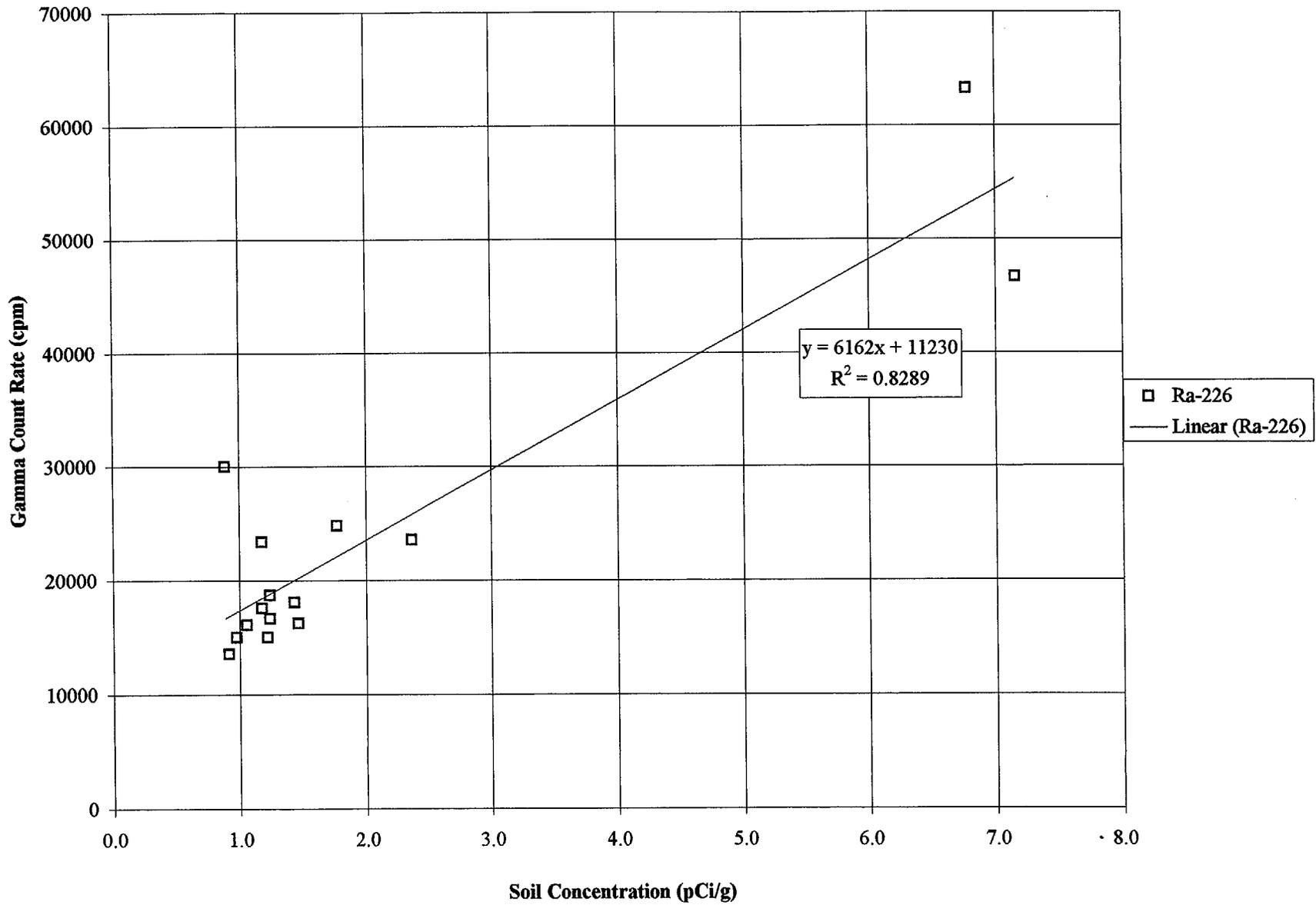
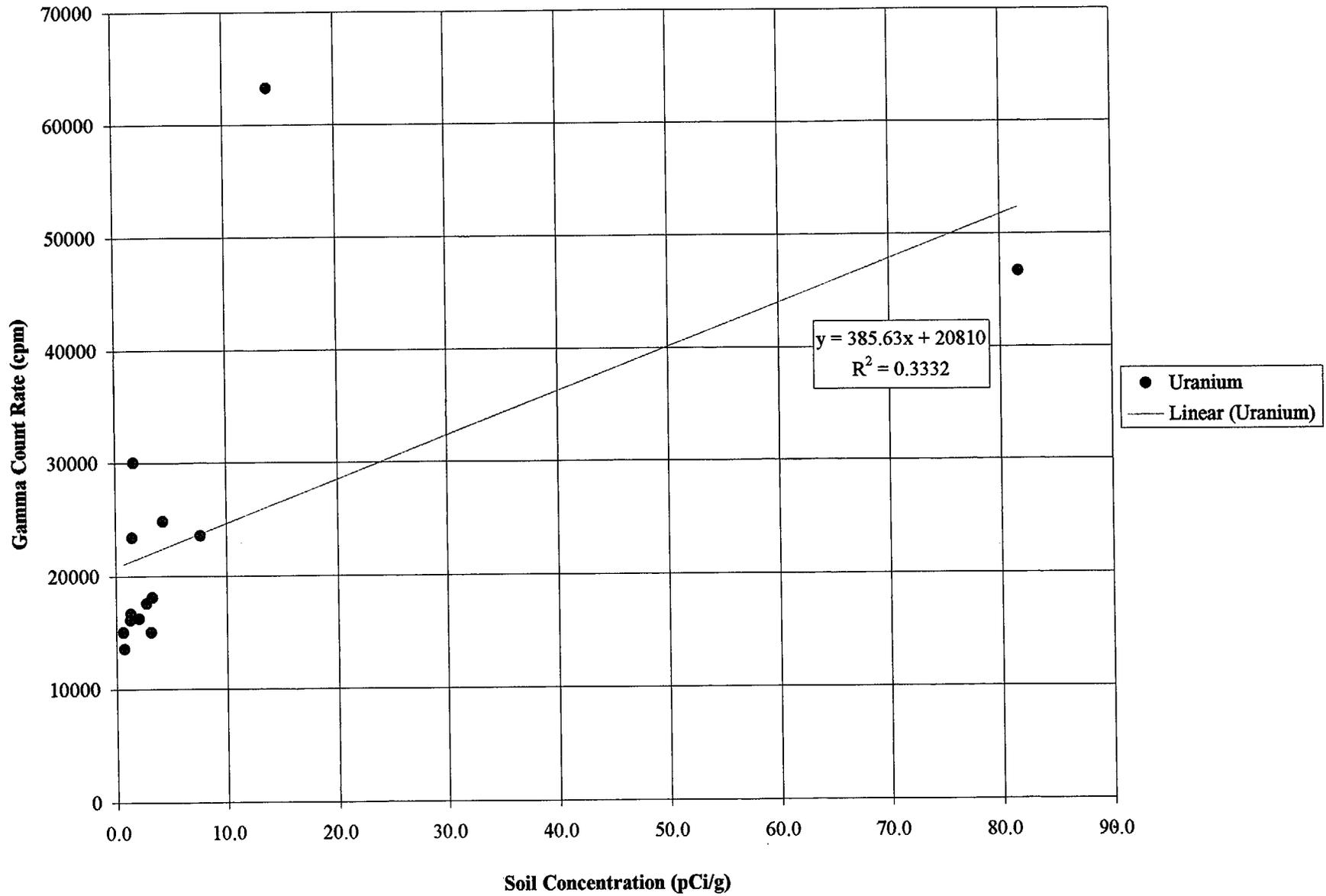


Figure 7-2 Gamma Count Rate as a Function of Ra-226 Concentration in Soil



**Figure 7-3 Gamma Count Rate as a Function of Uranium Concentration in Soil**

NaI count rate instruments, as shown in Figure 7-4, shows that 25,000 cpm corresponds to about 20  $\mu\text{R}/\text{h}$  on the Model 19. While the Model 19 may be a useful instrument in some very high exposure rate situations, the factor of approximately five better sensitivity of the Model 44-10 along with the integrating-over-time feature of the Ludlum 2221/Ludlum 44-10 system (or equivalent) make it the preferred instrument for use at these low levels.

The data indicate that areas with average gamma count rates below 25,000 cpm are unlikely to contain uranium and/or Ra-226 concentrations higher than the upper variation in the natural background concentrations for those radionuclides at the Irigaray or Christensen Ranch Project. At this time, no additional contaminated areas are known to exist where correlation data may be obtained. Therefore, unless areas are identified during remediation, all 100-m<sup>2</sup> areas above 25,000 cpm will be remediated or sampled to assure that the cleanup criteria are met. If adequate data are obtained during remediation on which to base a more precise soil cleanup action level corresponding to the cleanup criterion, COGEMA may choose to petition the NRC for a change in the Decommissioning Plan.

### **7.2.2 Gamma Surveys for Characterization and Verification**

Two methods are proposed for conducting site gamma surveys, one the GPS-based radiological survey system and the second being the equivalent conventional method using a Ludlum 2221 ratemeter/scaler and Model 44-10 detector. Since the methods differ only in data recording and management, there are no apparent differences in the accuracy of the results. The surveys are described and COGEMA will decide which method to employ.

#### Gamma Surveys and Mapping Using Global Positioning System

The GPS-based radiological survey will be done using equivalent equipment to that used in the correlation studies. The gamma-mapping system consists of digital gamma-ray monitoring equipment coupled to a Ludlum Model 44-10, a 2-inch by 2-inch NaI(Tl) detector. The digitized radiological count rate data are recorded once every two seconds by transmission to a Trimble ProXRS GPS receiver which automatically tags the data with the coordinates at the time the data count rate is received. The ProXRS, manufactured by Trimble Navigation, is state-of-the-art land surveying

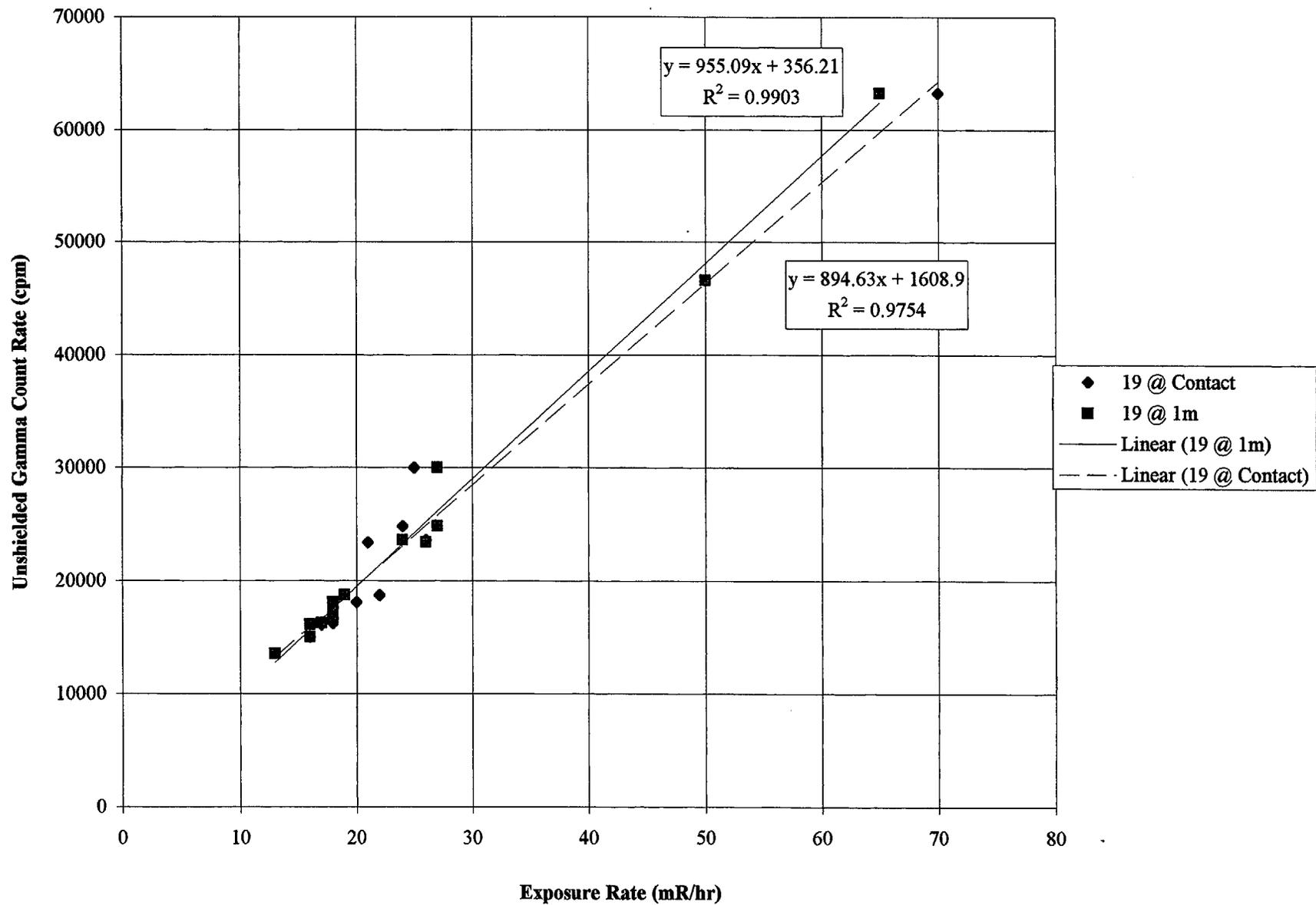


Figure 7-4 Relationship between Ludlum Model 19 and Ludlum Model 44-10 Readings

equipment, employing the use of satellite global positioning system (GPS) technology. The accuracy of the coordinates is better than one meter while collecting data.

The high accuracy is attained by placing a base receiver at a known surveyed marker within a few miles of the survey. The location of the base station (as determined by the satellites) is recorded each second. The error in this determination is then used to correct the perceived location of the data collection units (Rovers). An alternate to a local base receiver is to use a location correction factor for the area that is beamed to the site from a satellite. Either method allows one to attain accuracy better than one meter.

The data are collected in a data logger and later downloaded into a computer equipped with proprietary software. The data are then loaded into the ArcView GIS or other software for mapping and developing isocontours.

A gamma survey will be done over the extent of the affected areas. Gamma count rate isocontour lines at the action level will be used to define where remediation is required. After the remediation, the area will be resurveyed and the new data added to the database. This iterative procedure will be applied until all areas are determined to meet the action levels.

In the verification phase, the average count rate over each 100-m<sup>2</sup> grid block is calculated by downloading the data into a data base management computer application. The data records within each grid block are counted, averaged, and assessed as to whether the grid block meets verification criteria.

Function checks for the equipment will be performed at the beginning of each work shift using standard operating procedures. In addition, standard operating procedures will be used for operating the GPS-based radiological survey equipment as well as processing the data.

#### Radiological Surveys and Mapping Using Conventional Methods

Gamma surveys may be conducted using the same type of radiological survey equipment described above other than the data will be recorded manually and presented on maps with isocontours using computer assisted means. Grid blocks of 33.3-ft by 33.3-ft (approximately 100 m<sup>2</sup>) will be established

over the affected area. In order to determine the average gamma count rate within a grid block, the Ludlum Model 2221/Model 44-10 combination will be used to integrate the count rate while a technician walks the area for one minute. Correlation studies at mill sites have demonstrated that this results in a good correlation with the Ra-226 in the soil.

### **7.2.3 Excavation Control Monitoring**

Remediation of contaminated soils will be done by excavation. The purpose of excavation control monitoring is to guide the removal of contaminated material to the point where it is highly probable that an area meets the cleanup criteria. Monitoring equipment and action levels developed in the calibration studies will be used for excavation control monitoring. A technician will monitor the soil after the removal of layers of soil until the instrumentation shows that the levels are below the action level. No documentation of the results is done since the verification data will serve to demonstrate compliance with the cleanup standards. For large areas, a GPS based survey may be performed periodically to predict the progress of the excavation.

Other areas requiring contamination removal below the top 15-cm surface layer include piping trenches, deep excavations beneath building foundations or pond liners, or other areas where backfilling the excavation will be required. For areas exhibiting contamination below the top 15-cm and where backfill will be required, excavation control monitoring will be done using the same detector (or a detector with proven response characteristics) as used in the calibration study, considering the appropriate action level and adjusting for geometry factors. The cleanup limit for deep excavations where backfill is applied is 15 pCi/g for Ra-226, and 600 pCi/g for U-nat. Combinations of Ra-226 and U-nat will be limited to the sum of the fractions as recommended in the NRC Benchmark Dose Assessment method.

In order to limit the chemical toxicity exposures and implement ALARA (see Section 7.1), COGEMA is proposing a U-nat concentration cleanup goal for the top 15-cm surface layer of 150 pCi/g and the subsurface 15-cm layers to 400 pCi/g, averaged over 100 m<sup>2</sup>. The ALARA goal for subsurface Ra-226 contamination is 10 pCi/g above background, averaged over a 15-cm thick layer of 100 m<sup>2</sup> area.

#### **7.2.4 Soil Cleanup Verification Survey and Sampling Plan**

A final gamma survey of the affected area will be performed using the GPS-based equipment or conventional equipment as described above. For the GPS-based survey, a minimum of 7 data records in each 100-m<sup>2</sup> gridblock will be used to obtain the average gamma count rate for the affected areas of the site. For conventional surveys, a 1-minute integrated count while walking the area will be used as the average count rate.

For all grid blocks where the average count rate (bare Ludlum 44-10 detector) exceeds 25,000 cpm, the grid blocks will either be cleaned to below the action level and sampled, or the grid blocks will be sampled to assure compliance with the cleanup criteria. The five-point soil sampling procedure is given in SOP D-3. The sample will be analyzed to assure that the Ra-226 and uranium concentration complies with the cleanup criteria.

Standard Operating Procedures D-3, D-4, and D-5 include details of the soil cleanup verification surveys and sampling plans for surface and subsurface contaminated areas. The decommissioning Standard Operation Procedures are included as Appendix E.

#### **7.2.5 Laboratory Quality Assurance**

All verification samples will be sent to Energy Laboratories, Inc. (ELI) for analysis for radium-226 and uranium. For 90 percent of the samples, the entire sample will be transported to ELI. Ten percent of the samples will be selected at random and split, one part going to ELI and the other part to another vendor laboratory.

The results from the two vendor laboratories will be evaluated by assuring that the error bars overlap at the three standard deviation levels for all samples having measured Ra-226 concentrations greater than 1 pCi/g. That is, if the sample results for laboratories A and B are reported as  $C_A \pm 3\sigma_A$  and  $C_B \pm 3\sigma_B$ , where  $\sigma$  is the standard deviation, COGEMA will conduct an investigation if the following condition is not met:  $|C_A - C_B| \leq |3\sigma_A + 3\sigma_B|$ . The investigation may include having one or both laboratories repeat their analysis. The reason for not including the test for results less than 1 pCi/g is that the agreement at these low levels is normally not a good indicator of laboratory quality. For

small values, the large relative errors almost always allow the above test to be met. It has been our experience that the above test is very difficult to pass for a large set of samples and therefore we may expect sample results that never agree even after the subsequent investigation and further analyses. We however should expect that no bias exists between the two sets of vendor lab data. The bias will be determined by performing a linear regression between the data pairs. Any bias should be less than the difference between the cleanup limit and the highest value measured in the set of verification samples. Other statistical tests may be performed such as those to identify data outliers prior to assessing the bias.

#### **7.2.6 Field Measurements Quality Control**

The quality of field tasks related to measurements will be maintained through the use of standard operating procedures. Confirmation soil samples will be taken according to SOP D-3 and SOP D-5 (see Appendix E).

Gamma measurement quality will be controlled by the use of SOPs for assuring that the gamma instrument response is identical to that used in the preliminary survey (to develop the gamma action level) and a uniform response is maintained throughout the decommissioning period. Gamma function checks for NaI detectors used will be matched to those in the preliminary survey by using the same detectors and/or detectors with similar response characteristics.

If the GPS-based radiation survey is done, documented set-up procedures will be used to assure proper operation of the system. In order to provide daily checks that the positioning system is working properly, a check of the position coordinates at a known location will be done at the beginning and end of each work day, according to SOP D-4, Function Check of Equipment for Soil Cleanup Surveys. SOP D-4 also includes source and field operational checks for the radiation detection systems.

All radiation detection components will be calibrated at a 12-month frequency or after repairs.

The widely differing results between laboratories can be explained by the fact that it is difficult to

estimate the error for the analysis of a particular sample. It has been our experience that commercial laboratories report an underestimate of their errors, often indicating that the errors are the counting statistical errors only. They ignore the larger, often unknown, other statistical and systematic errors associated with the analysis. These include a systematic bias of up to five to ten percent due to errors in the calibration standards, errors associated with determining the chemical extraction yield for radiochemical analysis, and the potentially very large error associated with aliquoting a small sample from the larger sample. In order to assess the aliquoting error accurately, it would be necessary to perform analyses on several aliquots taken from the same large sample. This is of course costly and almost never done. We therefore, as indicated above, expect several samples to not meet the criterion for agreement even after the investigation has been completed. We believe that the overall QA program will, however, provide confidence that the analyses are acceptable and that the site meets the cleanup goals.

## **8.0 Radiation Safety Program**

The Safety Department will monitor decommissioning activities to ensure that occupational radiation exposure levels are kept as low as reasonably achievable during decommissioning. The Radiation Safety Officer (RSO), Radiation Safety Technician or designee by way of specialized training, will be on site during decommissioning activities where potential radiation exposure hazards exist. In addition, a Safety and Environmental Review Panel (SERP) will be used to evaluate changes in the decommissioning process or procedures as per Standard Operating Procedure SOP PBL-1. The SERP will determine if a change conflicts with license requirements, and if there is any degradation in the safety or environmental programs. The SERP will document its findings and recommendations. If the changes are not approved by the SERP, COGEMA is required to submit an application for a license amendment to the NRC.

### **8.1 D&D Task Analysis**

Most of the decommissioning activities are not significantly different than those conducted during mining operations. This includes cutting and/or removal of contaminated material and equipment from the process facilities, contaminated pipe crushing, tank entries to remove contaminated media, and decontamination of equipment using acid solutions or by sandblasting. Also, COGEMA has recently completed a partial decommissioning of four small evaporation ponds by removing the sediment and liners. Where applicable, these jobs were evaluated by the Safety Department and Radiation Work Permits were often issued. With the exception of work conducted inside the yellowcake dryer furnace or scrubber, the concentrations of airborne uranium exposed to the worker was less than the approved DAC's and resulted in no or insignificant assigned doses. The current Decommissioning Procedures are provided in Appendix E. Additional procedures will be added as needed.

Dismantling the dryer furnace poses the largest potential for worker exposure. A SOP will be written and reviewed with employees prior to conducting this task. The SOP will require respirator use, air sampling and urine sampling as part of the health protection plan. Before decommissioning,, the furnace's interior will first be cleaned of the residual dried yellowcake, with the scrubber fan and scrubber operating. This will provide a negative pressure inside the furnace and

limit yellowcake releases to the work area. If the unit is to be removed intact, the outlets and inlets will first be disconnected and capped. If the furnace is to be removed in sections, its interior will also be flushed with water to further reduce yellowcake emissions.

Fall hazards will be the main concern during dismantling of the buildings and equipment. Elevated sections of the buildings and tanks will likely require the use of a crane and other specialized equipment such as manlifts. Operators of such equipment will be certified or tasked trained. All workers will be required to wear hard hats and use fall protection where needed.

## **8.2 Personnel Training**

All workers employed during decommissioning, whether contractor employees or COGEMA Mine employees, will be given specialized training for minimizing radiological exposures in addition to industrial safety training.

Initial radiation and industrial safety training for COGEMA employees will be conducted as outlined in SOP S-21, Training Plans. This procedure is in accordance with NRC Reg. Guide 8.31 and the approved Mine Safety and Health Administration (MSHA) training plan. The training plan procedure requires a minimum training of 24 hours for new employees and two hours of quarterly refresher training. The training will be given by the RSO and/or other qualified instructor(s).

The extent of contractors training will be based on the type and degree of hazards applicable to their specific work. At a minimum, they will receive hazard training as outlined in SOP S-21, which covers both radiation and industrial hazards. Additional specialized safety training will be given to all affected employees whenever new or unusual hazards become evident during decommissioning.

## **8.3 Standard Operating Procedures (SOPs)**

The radiation safety program utilized during decommissioning will be based upon the existing ALARA program and SOPs, which have provided a sound radiation safety program during production operations and are also applicable for decommissioning activities. The Health Physics Procedures and the Decommissioning Procedures will govern the radiation safety program during

decommissioning. The health physics procedures (currently 29) have been submitted to the NRC (COGEMA, 2000). The Decommissioning Procedures are provided in Appendix E of this report.

#### **8.4 Respiratory Protection Program**

The existing respiratory protection program will be maintained during decommissioning. The approved program is detailed in SOP HP-21, Respiratory Protection Program, which includes policies, use approval, use and responsibilities, respirator and cartridge selection, training, limitations, and fit check/testing.

#### **8.5 Radiation Work Permit (RWP) Program**

SOP HP-11, Radiation Work Permits, will be integral to the radiation safety aspect during decommissioning. This procedure outlines the requirements and limitations for RWP's, and the use of the Radiation Work Permit Form.

Each work day, the radiation safety department will review the planned decommissioning activities in order to determine what RWP's are needed, if any. The potential for industrial safety hazards to the worker and the protective measures needed, will also be identified during the work review.

#### **8.6 Health Physics Surveys and Dose Calculations**

Health physics surveys conducted during decommissioning will be guided by applicable sections of 10 CFR 20 and USNRC Regulatory Guide No. 8.30 entitled "Health Physics Surveys in Uranium Mills" and the many applicable Health Physics SOPs.

The current radiological monitoring program (for production) will continue as listed in Table 5.11 of the 1996 License Renewal Application (COGEMA, 1996) until this plan is approved. At that time the radiological exposure and contamination monitoring given in Table 8-1 will be conducted. Table 8-1 is revised for restoration and decommissioning by eliminating the annual external survey for beta radiation and the daily ventilation inspections. The table also reduces the surface contamination survey (swipes) frequency from weekly to monthly.

**Table 8-1 Radiological Exposure and Contamination Monitoring Summary  
Irigaray and Christensen Ranch Projects**

Survey Type	Survey Locations	Survey Frequency or Timing
Airborne uranium grab samples	Indoor process areas	Monthly
	Indoor process areas > 25% DAC	Weekly
	Worker breathing zone	When required by RWP
Airborne uranium continuous sample	Drypack work stations	During dryer operation
Radon daughters grab sample	Indoor process areas	Monthly
	Indoor process areas > 25% DAC	Weekly
Gamma exposure	External surfaces in process areas	Quarterly
	Posted radiation areas	Monthly
Alpha contamination swipe	Lunchrooms, control rooms, change rooms, restrooms	Monthly
	Used respirators	After washing
Alpha contamination	Skin and clothing of personnel	Prior to leaving a restricted area
	Equipment/material surfaces	Prior to release
Alpha contamination & gamma exposure	Yellowcake or byproduct shipment containers and transport vehicle	Prior to release
Walk-through inspections of radiation control practices	Christensen Plant	Weekly
	Irigaray Plant	Weekly but daily when dryer operating

Annual beta surveys were eliminated because of historically low exposures compared to the dose limits. Past beta surveys were conducted only for information purposes. The highest beta exposure during year 2000 was 2.2 mrem/hour in the drypack furnace room, however employee exposure time in the drypack furnace room continues to decrease as less yellowcake is dried during the restoration process. The maximum annual employee exposure in the drypack furnace rooms during restoration is estimated at only 16 hours. Excluding the furnace rooms, none of the other beta exposure surveys exceeded 0.31 mrem/hour, which are minimal compared to the annual shallow-dose limits of 15 rem for the eye lens and 50 mrem to any other extremity.

Although daily ventilation inspections were eliminated, they are included as part of the weekly in-plant inspections, which are required in Section 11.5 of the newly amended license. Weekly inspections are considered adequate because none of the ventilation systems, other than the dryer scrubber system, are needed to maintain airborne radionuclides below the action level (25% of DAC). Note that the dryer scrubber system is monitored continuously during operation. As amended in License Section 11.5, daily walk-through inspections of the Irigaray facility will be conducted during operation of the yellowcake dryer, to determine that radiation control practices are being implemented appropriately.

Surface contamination swipe frequency was changed from weekly to monthly because of historically low surface activity levels that have not exceeded the NRC limit (1,000 dpm/100cm<sup>2</sup>) and rarely exceeded the internal action level of 100 dpm/100cm<sup>2</sup>.

The health physics surveys will be used to determine if any radiation doses need to be assigned to the affected workers. The dose calculations will be conducted as outlined in SOP HP-5, Internal and External Occupational Dose Calculations.

### **8.7 Shipments of Radioactive Materials**

Shipments of radioactive equipment and materials will be conducted to meet the DOT requirements,

as outlined in Sections 5.3 and 5.4. Should an accident occur during one of these shipments, the notification and response procedures will be followed as outlined in SOP E-11, Transportation Accidents Involving Radioactive LSA Material.

### **8.8 Records and Reports**

Survey documents and calibration records will be maintained for a minimum of five years as specified in License Section 11.6. Shipping records of transferred source or byproduct material will be maintained until the NRC terminates the existing License SUA-1341, as specified in 10 CFR 40.61 (2). All existing reporting requirements, as specified in the license and NRC regulations, will be continued during the decommissioning.

## **9.0 Environmental Impacts**

### **9.1 Land Use**

As stated in the 1996 License Renewal Application and the NRC Environmental Assessment dated June 1988, the primary impact on the land use through the life of the project (including decommissioning) is the loss of grazing capacity. The impact is temporary and will be reversed during decommissioning.

### **9.2 Air Quality**

As during production operations, air quality impacts from decommissioning activities will be minimal, and likely decrease as it progresses. Fugitive dust will decrease due to less road traffic from employees and vendors. Contractor traffic will increase at various times during decommissioning, particularly with the transport of byproduct and decommissioned materials, but the impact will still be minimal. Byproduct material shipments will be transported in tarped or enclosed containers, pursuant to DOT regulations, as cited in Sections 5.3 and 5.4. Therefore, airborne uranium releases from shipments are not a concern. With mining ceased, the yellowcake drying and packaging facility will be used on a very limited basis. Therefore, airborne uranium emissions from the dryer stack will be greatly reduced. Radon gas released from recovered groundwater will decrease, since total flow rates from the wellfields will be reduced to meet the restoration capacities.

### **9.3 Wildlife**

No significant adverse impact to wildlife was noted during operations or is expected during decommissioning. A golden eagle nest, located within one-fourth mile from the Christensen Ranch plant and wellfield, has continued to be successfully used by the eagles throughout operations. This was the only threatened species monitored. No evidence of any other threatened or endangered species, including the unlisted Mountain Plover, has been noted during operations. If evidence of the Mountain Plover is found, COGEMA will consult with the Fish and Wildlife Service as described in NRC License Section 9.13.

#### **9.4 Surface Water**

As stated in the 1996 License Renewal Application, sediment yields and total runoff may increase for a very short period of time during and immediately following decommissioning and reclamation activities. The impacts to surface waters within and adjacent to the licensed area, will not be significant because of their short duration and the limited size of the disturbance. Efforts to minimize soil erosion will follow COGEMA's storm water best practices program.

The current surface water sampling (for production) will continue as listed in Table 5.25 of the 1996 License Renewal Application (COGEMA, 1996), until this plan is approved. At that time the surface-water sampling program given in Table 9-1 will be conducted. Table 9-1 is revised for restoration and decommissioning by the elimination of the annual Powder River sample (IR-5). IR-5 is located approximately 4 miles from the Irigaray Site. Since surface discharge waters enter Willow Creek, it is more appropriate to continue sampling Willow Creek instead of Powder River.

#### **9.5 Archaeological Sites**

As required by License Section 9.9, any work resulting in the discovery of previously unknown cultural artifacts shall cease and no disturbances shall occur until authorization is received from the NRC.

#### **9.6 Groundwater**

Groundwater monitoring during restoration will be conducted as per the schedule given in Table 6.2 of the 1996 License Renewal Application (COGEMA, 1996). This includes sampling the designated restoration baseline wells, the recovery stream composite, and all monitor and trend wells. The schedule is broken down into three phases (post-mining, restoration and post-restoration/stability).

The current regional groundwater sampling of ranch wells (for production) will continue as listed in Table 5.25, 1996 License Renewal Application (COGEMA, 1996), until this plan is approved. At that time the regional groundwater-sampling program given in Table 9-1 will be conducted. Table 9-1 is revised for restoration and decommissioning by reducing the sampling frequency from quarterly to annual. The reduction was based on many years of data which showed no concerning trends.

**Table 9-1 Environmental Radiological Monitoring Summary  
Irigaray and Christensen Ranch Projects**

Sample Type	Sample Locations	Frequency	Analysis
Regional groundwater grab sample	Christensen: 1. Christensen Ranch House 2. Ellendale #4 3. Willow Corral #32 4. First Artesian #1 5. Middle Artesian #2  Irigaray: 1. Willow#2	Annually	Uranium, Ra-226, Th-230, Pb-210, Po-210
Surface water grab sample	Christensen: 1. CG-05, Willow Creek upstream from site 2. GS-1, Willow Creek downstream from site 3. GS-03, Willow Creek 250 yards downstream from Mine Unit 3  Irigaray: 1. IR-14, Willow Creek upstream from site 2. IR-9, Willow Creek downstream from site 3. IR-17, Willow Creek adjacent to Production Unit 1	Annually	Uranium, Ra-226, Th-230, Pb-210, Po-210, TDS, SO4, Cl, Cond., Total alkalinity, pH, As, Se
Airborne radionuclides continuous sample	Irigaray only: 1. IR-1, downwind from the plant restricted area 2. IR-3, upwind from the plant restricted area 3. IR-4, north access road 4. IR-5, Brubacker ranch 5. IR-6, southeast access road	Weekly composites when the yellowcake dryer is operating	Uranium, Ra-226, Th-230, Pb-210

## **9.7 Environmental Radiological Monitoring**

The current environmental radiological effluent monitoring program (for production) will continue as listed in Table 5.23 of the 1996 License renewal Application (COGEMA 1996), until this plan is approved. At that time the environmental radiological monitoring summary given in Table 9-1 will be conducted. Table 9-1 is revised for restoration and decommissioning by eliminating sampling of radon, soil, vegetation and the yellowcake dryer stack. However, continuous sampling of airborne radionuclides from five surrounding locations will continue when the dryer is operating.

The environmental radiological monitoring changes were based on many years of data collection, which showed no concerning trends. During restoration and decommissioning it is expected that environmental radiological effluents will be no greater than in the past. Emissions from the yellowcake dryer stack will actually decrease since it will operate for only 2-3 weeks per year.

## **9.8 Non-Radiological Impacts**

The potential impacts from non-radiological components of byproduct material disposed of during ISL operations should be minimal, as are the radiological impacts. Liquid effluents that were routinely released from the operations consisted of treated restoration solutions and were in accordance with EPA/State of Wyoming NPDES permit requirements, which specifically regulate the non-radiological components of the effluent, as well as uranium and radium-226 concentrations. Recently, these liquid effluents have also become designated as NRC 11e(2) byproduct material and must meet the effluent limitations in 10 CFR 20, Appendix B. Liquid process wastes have been disposed of through evaporation or deep well injection.

Solid byproduct waste material will be removed from the Irigaray and Christensen sites in accordance with this decommissioning plan, and it can be assumed that associated non-radiological components of the byproduct will be removed with the radiological components. Byproduct material removed will be disposed of at Pathfinder's Shirley Basin mill tailings impoundment.

As for accidental releases of byproduct material, primarily spills in the wellfield areas, it has already

been shown that the radiological impact in the spill areas has been very minimal. The non-radiological constituent that could be of interest in the spilled lixiviant in the wellfields is selenium. The analytical results from the end-of-mining recovery composite samples from all wellfields at Christensen and Production Unit 6 at Irigaray show an average of 2.8 mg/l of selenium.

To understand the impact of this amount of selenium on the local soils, one must know the background selenium concentration in the soils. Background selenium concentrations in the local soils were not established prior to the mining activity, but are generally known to be high in the surface soils. According to the Geological Survey of Wyoming, Open File Report No. 88-1 ("Guide to Potentially Seleniferous Areas in Wyoming", compiled and mapped by James C. Case and James C. Cannia, January 1988), available data indicate that the Wasatch Formation in the Powder River Basin has selenium contents locally ranging up to 1,900 ppm. Five species of selenium indicator plants are also found within the Christensen permitted area (Source: Appendix D8 of the original 1987 license application to NRC for Christensen Ranch, incorporated by reference into the 1996 license renewal document). If the local soils were ever used for continuous, long-term irrigation (say over a 20-year period), a concentration of 2.8 mg/l selenium in the irrigation water could be of some concern (however, modeling of the long-term effects would be necessary to confirm this). Because of the instantaneous nature and limited volumes and area of the wellfield spills during operations, a build-up of selenium should not have occurred. Assuming that the local grasses and plants are already adapted to higher selenium concentrations in soils, the small amount of spilled solution should not have significantly affected the local soils or plants. It is also probable that the cleanup of any radiologically contaminated soil will also remove any abnormal selenium concentrations, if they exist.

## **10.0 Post-Decommissioning Reclamation Procedures**

See Section 6.3, Surface Reclamation, of the 1996 License Renewal Application (COGEMA, 1996) for a complete discussion of post-decommissioning reclamation procedures. The reclamation commitments in the renewal application are incorporated into the license through Condition 9.3.

## **11.0 Decommissioning Schedule and Cost Estimate**

A preliminary schedule for the accomplishment of the decommissioning and reclamation of the Irigaray Project and Christensen Ranch Project is shown in Figure 11-1. Meeting this schedule is highly dependent upon the pace of groundwater restoration and receiving various regulatory approvals. As of this writing, groundwater restoration at the Irigaray Project is ongoing in two Production Units (#6 and 7) out of a total of nine. Restoration has been completed in the other seven Production Units. Completion of groundwater restoration at Irigaray is projected for late 2001, with wellfield decommissioning and surface reclamation to follow. Decommissioning of most plant facilities will commence in 2003, but will not be completed until groundwater restoration is finished at the Christensen Ranch Project and all recovered uranium is processed. Groundwater restoration at the Christensen Ranch Project is also ongoing in four out of a total of five previously-mined Mine Units (#2, 3, 5, and 6). Projected completion of groundwater restoration is in 2005, with final decommissioning and surface reclamation to follow. Note that Mine Unit 7 was never placed into production and, therefore, well plugging/abandonment and general field reclamation can proceed independent of this decommissioning plan.

An updated restoration and reclamation surety estimate was provided to the NRC through submittal dated August 18, 2000. This estimate is based on the premise that a third party contractor is hired to conduct the reclamation. The estimate is very detailed and addresses the anticipated costs for all aspects of the decommissioning including groundwater restoration, process plant(s) equipment removal and disposal; plant(s) buildings demolition and disposal; process pond(s) sludge, liner, leak detection systems and contaminated soils (if any) removal and disposal; well abandonment; wellfield equipment removal and disposal (assumes removal and disposal of ALL buried piping as byproduct material, which may not be necessary); topsoil replacement and revegetation; removal of all ancillary materials such as roads, culverts, power lines, power poles, fencing, and trunkline manholes; and final revegetation of all disturbed sites. The surety estimate also includes a 21.5 percent contingency to provide for third party project design, contractor profit and mobilization, project management, insurance, monitoring and unknowns.



As the current surety estimate provides for all aspects of the decommissioning plan, no changes are recommended at this time. However, as experience is gained during the decommissioning program, COGEMA fully expects that the estimate will be adjusted on an annual basis to reflect the newly gained experience. Because the surety estimate is currently under review by the NRC, and will change on an annual basis, it is not included with this decommissioning plan.

## **12.0 Final Decommissioning Completion Report**

Within six months of the conclusion of decommissioning and surface reclamation, a report containing all applicable documentation will be submitted to the U.S. Nuclear Regulatory Commission and the Wyoming Department of Environmental Quality.

### 13.0 References

COGEMA, 1996. Permit to Mine No. 478, A-2 Update and U. S. NRC License Renewal Application, Source Material License SUA-1341, January 5, 1996, COGEMA Mining, Inc., P. O. Box 730, Mills, WY 82644.

COGEMA, 2000. Decommissioning Plan for Irigaray and Christensen Ranch Projects. May, 2000. COGEMA Mining, Inc., P. O. Box 730, Mills, WY 82644.

1985 Report. Revised Application for Renewal of License SUA-1341, Irigaray Mine Site, October 28, 1985. Westinghouse Electric Corporation, Box 355, Pittsburgh, PA 15230.

1987 Report. Environmental Audit-Irigaray Mine. April 22, 1987. Unpublished report prepared for Arnold & Porter by Canonic Environmental Services, Englewood, CO.

1988 Application. January 5, 1988. Christensen Ranch Amendment Application to WDEQ Permit to Mine No. 478 and NRC License SUA-1341. Prepared for Malapai Resources Company, Casper WY, by Radiant Energy Management, 10854 Diane Drive, Golden, CO 80403.

NUREG-1549. draft Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination. July 1998. Division of Regulatory Applications, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D. C. 20555.

NUREG-1575. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). Published jointly by the U.S. Nuclear Regulatory Commission, U. S. Environmental Protection Agency, U. S. Department of Energy, and the U. S. Department of Defense. December, 1997.

NUREG-1620. Draft Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act, undated. Division of Waste Management, Office of Nuclear Material Safety and Safeguards, Washington, D.C. 20555-0001.

ANL-1993. Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0. Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439

NUREG/CR-5512, Vol. 1. Residual Radioactive Contamination from Decommissioning. Final Report. October 1992. Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent (Also PNL-7994R). Pacific Northwest Laboratory, Richland, WA. 99352

NUREG/CR-5512, Vol. 2. Residual Radioactive Contamination From Decommissioning. User's Manual. Draft Report. May 1999. U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001

NUREG/CR-5512, Vol. 3. Residual Radioactive Contamination From Decommissioning. Parameter Analysis. Draft Report for Comment. October 1999. U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001

PMC, 1997. Soil Cleanup Verification Survey and Sampling Plan for the Shirley Basin Mill Tailings Site. April 1997. Pathfinder Mines Corporation, P. O. Box 730, Mills, Wyoming 82644