UNITED STATES NUCLEAR REGULATORY COMMISSION

ENVIRONMENTAL ASSESSMENT

PREPARED BY THE

URANIUM RECOVERY FIELD OFFICE

IN CONSIDERATION OF THE RENEWAL OF

SOURCE MATERIAL LICENSE SUA-1358

FOR

THE UMETCO MINERALS CORPORATION

WHITE MESA URANIUM MILL

Dated: SEP 2 6 1985

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1.0 INTRODUCTION

1.1 Description of and Need for the Proposed Action

By application dated January 30, 1985, Umetco Minerals Corporation (Umetco) requested renewal of NRC Source Material License No. SUA-1358 authorizing uranium milling activities at their White Mesa mill located in San Juan County, Utah. The mill is currently in a shutdown status under a timely renewal since the previous license expired on January 30, 1985. The licensee projects resuming milling operations by about October 1, 1985. The proposed action is to issue a renewal of the subject license authorizing operation of the facility for maximum production of 4380 tons of U_3O_8 per calendar year.

The necessity for the White Mesa milling facility was discussed in Section 10 and Appendix B of the Final Environmental Statement (FES) for the White Mesa Project (NUREG-0556) dated May, 1979. The necessity for renewing the license is essentially the same as discussed in the FES.

1.2 Background Information

By letter dated February 6, 1978, Energy Fuels Nuclear, Inc. (EFN) applied to the Nuclear Regulatory Commission (NRC) for a Source and Byproduct Material License to construct and operate a uranium milling facility located approximately 9.5 km (6 miles) south of Blanding, Utah (see Figure 1, Appendix A). Following issuance of the FES in May, 1979 and the staff's Safety Evaluation Report (SER) in August, 1979, Source and Byproduct Material License No. SUA-1358 was issued on August 7, 1979.

The mill operated on a continual basis until February, 1983 and has been in a standby mode until the present time. Umetco purchased a controlling interest in the mill in January, 1984 and was designated operator and licensee by Amendment No. 26 issued by the NRC on December 5, 1984.

1.3 Review Scope

This environmental assessment of Umetco Minerals Corporation's request for renewal included evaluations of the January 30, 1985 renewal application; a revised renewal application dated May, 1985; additional information submitted by letters dated May 8 and May 10, 1985; and environmental monitoring reports submitted since issuance of the original license.

Umetco's proposed programs were evaluated against NRC regulations as specified in 10 CFR 20 and NRC staff policy as specified in the following: (1) Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills," (2) Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment;" and (3) Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems For Uranium Mill Tailings."

2.0 ENVIRONMENTAL AND RADIOLOGICAL IMPACTS

2.1 Land Use

All operations to be authorized by the renewed license will be conducted within the confines of the existing site boundary. The project site consists of 1052 ha (2600 acres) of private land together with 726 ha (1725 acres) of mill site claims. Surface area owned by Umetco is shown on Figure 2 (Appendix A) and includes most of Section 28 and portions of Sections 21, 22, 27, 32 and 33 of T.37S, R.22E, and Section 16 of T.38S, R.22E. The mill occupies 34 acres (14 ha). At the end of the proposed period of renewal (1985 through 1991) the tailings disposal cells will occupy another 132 acres (54 ha).

The region is characterized by an arid climate, a sparse population and diverse topography. Primary land uses includes livestock grazing, wildlife range, and exploration for minerals, oil and gas. The area within 8 km (5 miles) of the project site is predominantly range land owned by residents of Blanding, although much of the land in San Juan County is Federally owned. The nearest resident in the prevailing wind direction is located at the Blanding Airport approximately 5.7 km (3.6 miles) northeast of the mill. Approximately 5.6 km (3.5 miles) southeast of the project site is the White Mesa Reservation, a community of 260 Ute Indians.

A historical survey was conducted in the project vicinity as part of the initial application and six historical sites were identified. However, none of the sites is in an area which will be affected by operations at the White Mesa mill.

Archeological surveys of the project site conducted in 1977 and 1979 identified 121 areas which were once affiliated with the San Juan Anasazi Indians who occupied this area of Utah approximately 686 years ago. As a result of the archeological findings, a memorandum of agreement (MOA) between NRC, the Utah State Historic Preservation Officer and the Advisory Council on Historic Preservation was established to specify requirements necessary to minimize adverse impacts to the previously identified archeological sites. The requirements were incorporated into SUA-1358 as initially issued. The requirements have been subsequently modified following amendment of the MOA. The most recent modifications were incorporated into SUA-1358 through the issuance of an amendment on May 11, 1983. These requirements will be included in the renewed license.

To assure continued protection of the environment, the staff will require that the licensee conduct an annual survey of land use in the vicinity of the mill and conduct an archeological and historical artifact survey of areas not previously surveyed prior to their disturbance.

2.2 Operating Data

2.2.1 Air Particulate Sampling

Umetco's previous air particulate monitoring program consisted of five continuous environmental sampling locations. Three stations were located at the site boundary, one at the nearest residence, and one background station 15 km upwind from the site. The samples were analyzed for U-nat, Th-230, Ra-226, and Pb-210.

Since the White Mesa Mill terminated operations in February of 1983, the data reviewed for this renewal was collected during 1982 when milling operations were continuously performed. The data indicated that measured concentrations of U-nat, Th-230, Ra-226, and Pb-210 have been only small fractions of the 10 CFR 20 limits for unrestricted areas. A summary of this data is as follows:

1. U-nat concentrations did not exceed an annual average of 0.2% of the 10 CFR 20 limits.

2. Th-230 concentrations did not exceed an annual average of 12.1% of the 10 CFR 20 limits.

3. Ra-226 concentrations did not exceed an annual average of 0.13% of the 10 CFR 20 limits.

4. Pb-210 concentrations did not exceed an annual average of 0.8% of the 10 CFR 20 limits.

It should be noted that the concentrations measured include contributions from natural background.

2.2.2 Stack Effluent Sampling

Stack sampling has been performed at least semiannually since the mill began operation. The FES (Section 3.2) predicted a product loss from the yellowcake drying and packaging stack of 115 kg per year of which 104 kg would be U_3O_8. This resulted in a calculated release rate of 0.029 Ci/y for U-238. Actual stack sampling measurements performed in 1982 indicated releases of 97.5 kg of U-nat from the yellowcake stack, which corresponds to 0.027 Ci of U-238. The measured values compare favorably with the release values predicted in the FES.

The FES also estimated that 0.0016 Ci/y of Th-230, 6.2E-5 Ci/y of Ra-226, and 6.2E-5 Ci/y of Pb-210 would be released. Based on effluent monitoring data, the average releases during 1982 were 3.2E-5 Ci/qtr of Th-230 (1.3E-4 Ci/y), 1.0E-5 Ci/qtr of Ra-226 (4.1E-5 Ci/y), and 7.9E-5 Ci/qtr of Pb-210 (3.17E-4 Ci/y). All of the measured values were less than the predicted releases except for Pb-210. The calculated concentration of Pb-210 in the yellowcake stack, when flow rate was considered, did not exceed 17.5% of the maximum permissible concentration (MPC) for restricted areas in any quarter.

2.2.3 Radon Gas Monitoring

Radon gas monitoring was performed one week each month at the five stations utilized to collect airborne particulate samples. During 1982, measured radon gas concentrations did not exceed 11% of the MPC for unrestricted areas. The background during this same collection period measured 7.3% of the MPC.

2.2.4 Ground Water and Surface Water Sampling

Umetco previously performed quarterly sampling of nine monitoring wells, one control well upgradient of the tailings system, one drinking water well and two surface water sources. Samples were analyzed for five radionuclides and various chemical and physical parameters.

A staff review of the ground water quality indicated that downgradient monitor wells Nos. 2, 3, 4, 5, 11, 12 and 13 show a higher concentration of dissolved constituents than does the background well (No. 1). Because this has been observed since the time of the preoperational monitoring program, it probably represents normal variance in the ground water. Based on 1982 ground water monitoring data, the highest radionuclide concentrations measured were 0.08, 10, 0.09, 1.8 and 0.3 percent of the applicable MPC for U-nat, Ra-226, Th-230, Pb-210 and Po-210, respectively. No ground water anomalies have been observed. This situation is not unusual since the tailings retention system consists of synthetically lined cells.

Surface water radionuclide concentrations have not varied appreciably. The U-nat concentrations are higher than any other radionuclide and did not exceed 1.1E-8 uCi/ml (0.004 % of the MPC for unrestricted areas).

2.2.5 Direct Gamma Exposure

Direct radiation exposure measurements were made quarterly at the five air particulate monitoring stations. The highest exposure rate measured during 1982 was 37.3 mR/qtr including background and 11.7 mR/qtr above background.

2.3 Radiological Assessment

2.3.1 Introduction

This assessment addresses the radiological impacts from milling operations at the White Mesa site. The licensee desires to process 2000 tons/day of ore with an average ore grade of 0.6%, for a yellowcake production rate of 4,380 tons/year. This assessment presents a state-of-the-art evaluation of impacts from the White Mesa mill at a production rate of 4,380 tons of yellowcake per year.

Components of the radiological analysis presented in this section include estimates of the following: (1) annual releases of radioactive materials from the mill and tailings retention system, (2) resulting dose commitments to nearby individuals and the population within 80 km (50 miles) of the site, and (3) concentrations of radionuclides at the restricted area boundary. The calculated results are compared to measured background radiation and applicable regulatory limits. Tables and figures referenced in the text are provided in Appendix A.

2.3.2 Estimated Releases

A summary of the information and data assumptions used to calculate the annual releases of radioactive materials from the mill and tailings retention system is presented in Table 1. The estimated annual releases are presented in Table 2. More detailed descriptions of release estimates from the tailings cells and ore pad as well as descriptions of the models and assumptions used by the staff to perform the radiological impact assessment are provided in Appendix B. Release rates from the tailings retention system are based on the tailings management plan discussed in Section 4.0.

2.3.3 Exposure Pathways

Potential environmental pathways by which people could be exposed to radioactive effluents from the White Mesa Mill are presented in Figure 3. These pathways include inhalation of radioactive materials in the air, external exposure to radioactive materials in the air or deposited on ground surfaces, and ingestion of contaminated food products (i.e., vegetables, meat and milk).

2.3.4 Radiation Dose Commitments to Individuals

The nearest residence to the mill is the White Mesa Reservation, located approximately 5.6 km southeast of the mill. The airport, the nearest residence in the prevailing wind direction, is located approximately 5.7 km NE of the mill. In addition to calculating dose commitments to individuals residing at the nearest residences, the staff has also calculated dose commitments for individuals residing in Blanding, Utah, 9.95 km NE of the mill. Meat ingestion doses were calculated because cattle are grazed in the vicinity of the mill. Table 3 presents a summary of individual dose commitments calculated for these locations. These doses result from releases during the final year of mill operation, when environmental concentrations are expected to be at their highest level.

For the purposes of this assessment, the staff has assumed that ingestion doses at the White Mesa Reservation result from the consumption of meat from cattle grazed within 1 km of the mill center. There are no milk cattle in the vicinity of the mill but there is an orchard 3.54 km north of the mill center.

Table 4 presents a comparison of the annual dose commitment resulting from mill operations with the EPA radiation protection standard (40 CFR Part 190).

2.3.5 Radiation Dose Commitments to Populations

Projected environmental population dose commitments are presented in Tables 5 and 6. Table 5 presents 100 year dose commitments to the regional population within 80 km of the White Mesa mill for the final year of mill operation. Table 6 presents the total environmental dose commitments to the regional population within 80 km of the mill and the transcontinental population from operations over the renewal period of the White Mesa mill (1985 through 1991). Transcontinental dose commitments, as opposed to regional impacts, result entirely from the release of radon gas.

Both tables discussed above also contain a comparison of total dose commitments resulting from the White Mesa operation with dose commitments resulting from natural background.

2.3.6 Evaluation of Radiological Impacts to the Public

A review of Table 4, which compares individual dose commitments with the EPA 40 CFR 190 standard of 25 mrem to the whole body or any organ, indicates that individual dose commitments are small fractions of the standard. The highest calculated dose commitment is 4% of the EPA standard.

A review of Tables 5 and 6 indicates that regional and transcontinental dose commitments are only very small fractions of the dose commitments from naturally occuring background radiation.

2.3.7 Radionuclide Concentrations at Site Boundaries

The radiological assessment also included the calculation of projected radionuclide locations at eight site boundary locations during the final year of operation. A comparison of these projected concentrations with unrestricted area concentration limits specified in Appendix B to 10 CFR Part 20 is presented in Table 7. The highest projected concentration is 14.4% of the 10 CFR 20 limits for Th-230 and less than 1% for U-238. For the 1982 year of full operation, the highest annual averages of quarterly concentrations measured were 12.1% for Th-230 and 0.2% for U-238 of the 10 CFR 20 limits. Therefore, the projected highest concentrations compare favorably with the highest concentrations actually measured at the site boundary.

2.3.8 Summary

The radiological assessment performed by the staff indicates that both site boundary radionuclide concentrations and individual dose commitments are small fractions of applicable standards. However, the renewed license will require that the operator conduct an effluent and environmental monitoring program, the results of which must be reported to the Uranium Recovery Field Office, NRC, in accordance with 10 CFR 40.65. The licensee will also be required to conduct an annual land use survey of the environment near the mill and report the results of these surveys to URFO. Significant changes in regional population, grazing or land cultivation patterns near the mill would necessitate a revised radiological assessment, and could alter the conclusions in this assessment. URFO will continue to review the operator's future submittals to determine compliance with existing standards.

Additionally, the licensee will be required by license condition to assess all activities not previously evaluated in this environmental assessment or the FES for potential adverse impacts. If the evaluation indicates that the activity could result in a significant environmental impact, the licensee will be required to obtain NRC approval prior to initiating the activity.

3.0 EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAMS

3.1 Effluent Monitoring

The licensee has committed to perform sampling of mill stacks utilizing the EPA Method 5 isokinetic sampling procedure. Yellowcake stack sampling will be performed on a quarterly basis during operation of the facility. The particulate samples will be analyzed for U-nat on a quarterly basis and for Th-230, Ra-226 and Pb-210 on a semiannual basis. Ore stack sampling will be performed on a semiannual basis during operation of the facility. The particulate samples will be analyzed for U-nat, Th-230, Ra-226 and Pb-210. The licensee has indicated that monitored data will include ventilation system operation levels, process feed levels, particulate emission concentrations, isokinetic conditions and radionuclide emission concentrations. The staff will also require that all stack sampling include a determination of flow rate.

3.2 Airborne Particulate Monitoring

Umetco proposes to perform airborne particulate sampling at the five locations currently being monitored. The present low volume sampling system is to be replaced with high volume particulate samplers utilizing mass flow controllers to maintain an air flow rate of forty standard cubic feet per minute. Samplers will be operated continuously with an expected on-stream operating ratio exceeding ninety percent. Filters will be changed weekly with quarterly composition for radionuclide analysis. Samples will be analyzed for U-nat, Th-230, Ra-226 and Pb-210.

3.3. Radon and Direct Radiation Monitoring

Umetco proposes to perform continuous radon-222 monitoring at the five airborne particulate monitoring locations. System quality assurance will be provided by placing a duplicate monitor at one site continuously. The monitoring method consists of a Passive TLD system. Umetco proposes to exchange and read the TLDs monthly. The staff feels that quarterly readings of TLDs will minimize the relative error associated with each reading. The staff will therefore require that the TLDs be exchanged and read quarterly.

TLD badges supplied by Eberline, Inc., or equivalent, will be utilized at the five existing ambient particulate monitoring sites to determine ambient external gamma exposures. Each badge consists of a minimum of five TLD chips. Exchange of TLD badges will be on a quarterly basis.

3.4. Soil and Vegetation Sampling

Umetco's proposed programs for vegetation and soil sampling are discussed below. Forage vegetation samples will be collected three times per year from animal grazing areas near the mill site. The samples will be collected near the meteorological station, to the immediate west of this site, and by the south tailings area in the late fall, early spring and late spring. One to two kilograms of grass are to be collected from each site and analyzed for Ra-226 and Pb-210.

Soil Samples from the top one centimeter of surface soils will be collected annually at each airborne particulate monitoring site. A minimum of two kilograms of soil is to be collected per site and analyzed for U-nat and Ra-226.

3.5 Ground Water and Surface Water Sampling

3.5.1 Surface Water

Umetco proposes to sample Westwater and Cottonwood Creeks on a quarterly basis at locations upstream and downstream of the White Mesa Mill and tailings disposal site. Field monitored parameters include pH, specific conductivity and temperature. Laboratory monitored parameters include total dissolved solids, total suspended solids, and gross alpha concentrations.

In addition to the surface water monitoring program proposed by the licensee, the staff will require by license condition that analyses be performed semiannually on surface water samples for total and dissolved concentrations of U-nat, Th-230, and Ra-226.

3.5.2 Ground Water

Umetco proposes that ground water sampling of Monitor Wells 1, 2, 3, 4, 5, 11, 12, 13 and the culinary water well at the White Mesa facility continue on a quarterly basis. Wells will be pumped and the water quality monitored for pH, specific conductance and temperature during pumping with sample recovery occurring when these parameters stabilize to assure that a representative sample is obtained. The locations of the wells are shown on the map contained in Appendix B of the renewal application.

Umetco proposed that sample analysis be performed according to the schedule and for the 32 parameters listed in Table 5.5-1 of the renewal application. The proposed program consists of quarterly sampling and analysis of samples for various constituents on quarterly, semiannual, and annual frequencies, depending on the parameters. The staff concludes that annual analyses will not result in a reliable data base. The staff will therefore require that Umetco analyze for U-nat as well as seven chemical or physical parameters quarterly and Ra-226, Th-230 and Pb-210 as well as three additional chemical parameters semiannually. In addition, the staff will require that the ground water sampling data for the quarterly parameters be maintained in graphical form.

In order to assure that the requirements of the EPA 40 CFR 192 standard are met, the staff issued Amendment No. 29 to SUA-8681 on July 19, 1985. The amendment required the implementation of a detection monitoring program in accordance with 40 CFR 192. The applicable license condition will be included in the renewed license.

3.6 Quality Assurance for Environmental Monitoring

Umetco has submitted to the staff information regarding all aspects of the quality assurance program including environmental sample collection, handling and analysis. The staff has reviewed Umetco's quality assurance program and concludes that the program contains all the elements of an acceptable quality assurance program as specified in Regulatory Guide 4.15. The proposed program will ensure that all aspects of the environmental monitoring program are conducted in an acceptable manner.

The licensee did not submit proposed lower limits of detection (LLD) for the environmental monitoring program. Therefore, the staff will require by license condition that the licensee utilize LLDs in accordance with Section 5 of Regulatory Guide 4.14 for the analysis of samples collected pursuant to their environmental and effluent monitoring program.

3.7 Summary

The staff concludes that the effluent and environmental monitoring and quality assurance programs proposed by Umetco, as modified by the staff, are acceptable and in keeping with the guidelines presented in Regulatory Guides 4.14 and 4.15. In addition, the staff will require by license condition that the results of all effluent and environmental monitoring be reported to the Uranium Recovery Field Office, NRC, in accordance with 10 CFR 40.65.

4.0 TAILINGS MANAGEMENT

4.1 During Operation

The design of the complete tailings management system is presented in the report entitled, "Engineer's Report, Tailings Management System," June 1979 by D'Appolonia. Four cells were proposed for tailings disposal and one cell was designed for evaporation of water. To date, three cells have been constructed. All are synthetically lined. The initial phase of the tailings system has been in operation since May 1980. Cell 2 began operation in May 1980 for solids disposal and Cell 1 began operation in July 1981 as an evaporation pond. The second phase of the Tailings Management system consisted of Cell No. 3 which is also utilized for solids disposal.

No evidence exists that these ponds are allowing significant volumes of tailings fluid to escape to the surrounding environment. No water has been collected by the toe drain system in Cell No. 1. The small amount of water collected in the toe drain of Cell No. 2 was demonstrated to not be tailings liquid ("Leak Detection System Evaluation" by D'Appolonia dated December, 1981").

Through the period of renewal, only Tailings Cell Nos. 1-3 will be utilized by Umetco. No changes to the existing tailings retention system will be necessary as no additional capacity is needed. Any changes to the existing tailings retention system will require an amendment to SUA-1358.

Section 5.5.7 and Section 3.0 of Appendix D to the renewal application detail the tailings system inspection procedures. The sections describe the daily, weekly, monthly, quarterly and yearly inspections and the yearly technical evaluations to be performed and provide the inspection forms to be used. The inspection program is in accordance with Regulatory Guide 3.11.1. The licensee included a liner inspection program with sampling and analysis of any liquids in the underdrain system. These inspection programs will be incorporated into the renewed license.

The licensee committed to meeting a freeboard limit of 3.5 feet for Cell 1 and 5.0 feet for Cells 2 and 3. These freeboard requirements were approved by NRC during the initial evaluation of the tailings retention system and will be included in the renewed license. The staff will also require that mill tailings other than samples for research not be transferred from the site without specific prior approval of the NRC.

In order to prevent blowing tailings during operation and while a cell is being dried out, the staff will require that the licensee implement a program to minimize blowing of tailings and verify the effectiveness of the measures utilized by means of a weekly documented tailings area inspection. The staff will also require that the licensee install instrumentation on all tailings solution lines which will detect ruptures in the lines. This will assure line breaks do not go undetected.

4.2 Reclamation

The tailings reclamation plan currently in effect for the White Mesa mill was initially proposed by Umetco on May 14, 1982. It was revised on August 25, 1982 and again on August 26, 1983. The latter revision was incorporated into Source Material License SUA-1358 on September 12, 1983.

The current plan calls for a nine foot soil cover to be placed over all tailings. Outslopes of the pile will be flattened to 6H:1V slopes. Erosion protection consisting of two feet of rock on the top of the pile and four feet of rock on the outslopes will be placed on the reclaimed pile.

A staff radon attenuation calculation was performed to show that the cover thickness of 9 feet of soil as specified in the current reclamation plan will be sufficient to reduce the radon emanation rate to below 20 pCi/m^2-sec as specified in the EPA 40 CFR 192 standard. This calculation is illustrated in Appendix D. The staff evaluation indicates that approximately 7.5 feet of cover will provide the required attenuation. As the current reclamation plan calls for two feet of rock over the top of the cover, erosion due to sheet water flow and wind should be minimal over a 1000 year period. Therefore, the 9 feet of cover should provide radon attenuation over a 1000 year design life in accordance with 40 CFR 192.

In addition to two feet of rock on the top of the pile, four feet of rock erosion protection will be placed on outslopes of the pile, which will be graded to a 6H:1V slope. Erosion of the outslopes should therefore be minimal. The staff concludes that the current reclamation plan will be effective over a 1000 year design life in accordance with 40 CFR 192. However, the existing reclamation plan does not contain adequate detail regarding items such as the following:

(1) dewatering of the tailings
(2) interim stabilization of exposed tailings areas during the drying process

(3) settlement and consolidation monitoring of the tailings to determine when reclamation activities may be initiated
(4) timetables for and sequencing of reclamation activities.

The staff will therefore require that Umetco submit a revised reclamation plan for USNRC review and approval in the form of a license amendment. The revised plan will address all items listed above.

At present, the licensee maintains a parent company guarantee from Union Carbide Corporation per letter dated November 12, 1984, for millsite decommissioning and tailings reclamation. The staff will require that the surety arrangement in effect be updated annually and that a detailed breakdown of costs be provided to the NRC with the annual update.

Umetco Minerals Corporation owns the majority of the land on which the millsite and tailings cells are located. The remainder of the land is unpatented Bureau of Land Management land. The staff will require that the licensee either demonstrate federal ownership or make provision for transfer of the land to the federal government or the State of Utah prior to termination of the license.

5.0 CONCLUSION

Impacts resulting from milling operations at the White Mesa Mill are summarized below:

1. All activities are conducted within the existing site boundary, where operations have been conducted since 1980. Continuation of milling operations will not result in additional land disturbance above that already evaluated in the FES for the White Mesa Mill. In addition, all disturbed land will be reclaimed following cessation of milling operations.

2. Mill emissions, for the most part, have been less than emissions predicted in the White Mesa FES.

3. Airborne radionuclide concentrations measured at site boundary locations have been only small fractions of 10 CFR 20 concentrations.

4. Ground water radionuclide concentrations have been only small fractions of 10 CFR 20 values.

5. The radiological assessment performed indicates that individual dose commitments are small fractions of 40 CFR 190 limits.

Also, estimated concentrations of radionuclides in air indicate that even at the highest levels of expected release, the mill is in compliance with 10 CFR 20 limits for unrestricted areas.

It is the staff's conclusion that the impacts associated with renewal of Source Material License No. SUA-1358 are within the realm of impacts anticipated in the FES. Recognizing these impacts, the staff has available two alternatives with respect to the requested license renewal:

(1) Renew the license with such conditions as are considered necessary or appropriate to protect public health and safety and the environment; or

(2) Deny renewal of the license.

In the safety evaluation report prepared for this action, the staff has reviewed the licensee's proposed action with respect to the criteria for license issuance specified in 10 CFR 40, Section 40.32, and has no basis for denial of the license. Moreover, the environmental impacts described in this document do not warrant denial of the application. For these reasons, license denial is considered an unacceptable alternative.

Based on the environmental assessment presented in this document, the staff recommends that Source Material License No. SUA-1358 be renewed subject to the following license conditions:

1. Authorized place of use: The licensee's uranium milling facilities located in San Juan County, Utah.

2. The licensee is hereby authorized to possess byproduct material in the form of uranium waste tailings and other uranium byproduct waste generated by the licensee's milling operations authorized by this license.

3. For use in accordance with statements, representations and conditions contained in Sections 3.6.6, 5.1, 5.2, 5.3, 5.4, 6.2 and 6.3 and Appendix E, Section 5, of the license renewal application dated January, 1985 as revised May, 1985, except where superceded by license condition below.

   Whenever the word "will" is used in the above referenced sections, it shall denote a requirement.

4. The mill production per calendar year shall not exceed 4,380 tons of U_3O_8.

5. The licensee shall avoid by project design, where feasible, the archeological sites designated "contributing" in Attachment No. 2 to SUA-1358. When it is not feasible to avoid a site designated

"contributing" in Attachment No. 2, the licensee shall institute a data recovery program for that site based on the research design submitted by letter from C. E. Baker of Energy Fuels Nuclear to Mr. Melvin T. Smith, Utah State Historic Preservation Officer, dated April 13, 1981.

The licensee shall recover through archeological excavation all "contributing" sites listed in Attachment No. 2 which are located in or within 100 feet of borrow areas, stockpile areas, construction areas, or the perimeter of the reclaimed tailings impoundment. Data recovery fieldwork at each site meeting these criteria shall be completed prior to the start of any project related disturbance within 100 feet of the site, but analysis and report preparation need not be complete.

Additionally, the licensee shall conduct such testing as is required to enable the Commission to determine if those sites designated as "Undetermined" in Attachment No. 2 and located within 100 feet of present or known future construction areas are of such significance to warrant their redesignation as "contributing." In all cases, such testing shall be completed before any aspect of the undertaking affects a site.

6. Archeological contractors shall be approved in writing by the Commission. The Commission will consult with the SHPO regarding the qualifications of all archeological contractors and the quality of the laboratory facilities they will use. The Commission will approve an archeological contractor who meets the minimum standards for a principal investigator set forth in 36 CFR Part 66, Appendix C, and whose qualifications are found acceptable by the SHPO.

7. The licensee shall conduct an annual survey of land use (private residences, grazing areas, private and public potable water and agricultural wells, and non-residential structures and uses) in the area within five miles (8 km) of any portion of the restricted area boundary and submit a report of this survey to the USNRC, Uranium Recovery Field Office. This report shall indicate any differences in land use from that described in the last report.

8. The results of all effluent and environmental monitoring required by this license shall be reported in accordance with 10 CFR 40, Section 40.65 with copies of the report sent to the USNRC, Uranium Recovery Field Office. Monitoring data shall be reported in the format shown in the Attachment No. 3 to SUA-1358, "Sample Format for Reporting Monitoring Data."

9. Before engaging in any activity not previously assessed by the USNRC, the licensee shall prepare and record an environmental evaluation of such activity. When the evaluation indicates that such

activity may result in a significant adverse environmental impact that was not previously assessed or that is greater than that previously assessed, the licensee shall provide a written evaluation of such activities and obtain prior approval of the USNRC in the form of a license amendment.

10. The licensee shall maintain a USNRC approved surety arrangement adequate to cover tailings stabilization and reclamation, mill decommissioning, mill site reclamation, long term maintenance and monitoring, and ground water restoration as warranted. The licensee shall submit for USNRC review and approval a proposed revision to the surety arrangement within six (6) months of USNRC approval of a revised tailings area reclamation plan or approval of or revision to any ground water protection program. The revised surety shall be in effect within three (3) months of written USNRC approval. Furthermore, the licensee shall submit for USNRC review any proposed revision or update to the surety arrangement at least two (2) months prior to the proposed effective date. Along with each proposed revision or update and at least annually, the licensee shall submit documentation showing a breakdown of the costs and the cost basis for tailings stabilization and reclamation, mill decommissioning, mill site reclamation, long term maintenance and monitoring, and ground water restoration as warranted.

    If the licensee chooses to retain a corporate guarantee as the surety arrangement, the licensee shall provide for USNRC review and approval in the form of a license amendment the financial data listed in Items (a) - (d) of Attachment No. 4 to SUA-1358, NRC Self-Bonding Criteria, within four (4) months of the date of this license and annually thereafter.

11. Prior to termination of this license, the licensee shall provide for transfer of title to byproduct material and land, including any interests therein (other than land owned by the United States or the State of Utah), which is used for the disposal of such byproduct material or is essential to ensure the long term stability of such disposal site to the United States or the State of Utah, at the State's option.

12. The licensee shall not make any changes to the present tailings retention system without specific prior approval of the USNRC, Uranium Recovery Field Office, in the form of a license amendment.

13. The license shall implement an interim stabilization program for all tailings not covered by standing water. This program shall include written operating procedures and shall minimize dispersal of blowing tailings. The effectiveness of the control method used shall be evaluated weekly by means of a documented tailings area inspection.

The operating procedure shall be submitted for USNRC review and approval within three (3) months of the issuance of this license.

14. The licensee shall implement the effluent and environmental monitoring program specified in Section 5.5 of the renewal application as revised with the following modifications or additions:

    A. Stack sampling shall include a determination of flow rate.

    B. TLD chips used for radon monitoring shall be exchanged and read quarterly.

    C. Surface water samples shall also be analyzed semiannually for total and dissolved U-nat, Ra-226, and Th-230.

    D. Ground water samples from Monitor Wells 1, 2, 3, 4, 5, 11, 12, 13 and the culinary water well shall be analyzed quarterly for pH, specific conductance, chlorides, sulfates, TDS, and U-nat. Quarterly water level measurements shall also be made. Ground water samples shall be analyzed semiannually for arsenic, selenium, sodium, Ra-226, Th-230, and Pb-210.

    E. Data for the quarterly ground water parameters shall be maintained in graphical form and copies of the graphs included with the environmental monitoring reports submitted in accordance with 10 CFR 40.65.

    F. The licensee shall utilize lower limits of detection in accordance with Section 5 of Regulatory Guide 4.14, Revision 1 dated April 1980, for analysis of effluent and environmental samples.

15. The licensee shall submit to the USNRC, Uranium Recovery Field Office, by March 15, 1986 for review and approval in the form of a license amendment a detailed reclamation plan for the authorized tailings disposal area which includes the following:

    A. A post operations interim stabilization plan which details methods to prevent wind and water erosion and recharge of the tailings area.

    B. A plan to determine the best methodology to dewater and/or consolidate the tailings cells prior to placement of the final reclamation cover.

    C. Plan and cross-sectional views of a final reclamation cover which details the location and elevation of tailings. The plan shall include details on cover thickness, physical characteristics of cover materials, proposed testing of cover materials (specifications and QA), the estimated volumes of cover materials and their availability and location.

D. Detailed plans for placement of rock or vegetative cover on the final reclaimed tailings pile and mill site area.

E. A proposed implementation schedule for items A through D above which defines the sequence of events and expected time ranges.

F. An analysis to show that the proposed type and thickness of soil cover is adequate to provide attenuation of radon and is adequate to assure long term stability as well as an analysis and proposal on methodology and time required to restore ground water in conformance to regulatory requirements.

G. The licensee shall include a detailed cost analysis of each phase of the reclamation plan to include contractor costs, projected costs of inflation based upon the schedule proposed in item E, a proposed contingency cost, and the costs of long term maintenance and monitoring.

16. The licensee shall conduct a tailings retention system and liner inspection program in accordance with Section 5.5.7 and Appendix D, Section 3.0, of the renewal application. Notwithstanding any statements to the contrary, changes in inspection frequency shall require the approval of the USNRC in the form of a license amendment. Further, copies of the report documenting the annual technical evaluation shall be submitted to the Uranium Recovery Field Office, USNRC, within one month of completion of the report.

17. Mill tailings other than samples for research shall not be transferred from the site without specific prior approval of the USNRC in the form of a license amendment. The licensee shall maintain a permanent record of all transfers made under the provisions of this condition.

18. The licensee shall, by January 1, 1986, submit to the Uranium Recovery Field Office, USNRC, for review and approval in the form of a license amendment a plan for instrumentation which shall detect ruptures of the tailings discharge and solution return lines when these lines are being utilized. Indications of a possible rupture of these lines shall result in activation of an alarm in an occupied area of the mill. The instrumentation shall be tested daily, and testing documented, to ensure proper operation. The instrumentation shall be operational within sixty (60) days of USNRC approval.

19. The licensee shall implement a ground water detection monitoring program to ensure compliance to 40 CFR 192.32(a)(2) which includes the following elements:

A. The licensee shall monitor at the point of compliance and background wells for the following indicator parameters: Arsenic, Selenium and pH. The licensee shall utilize analytical techniques capable of providing lower limits of detection of 0.005 mg/l and 0.001 mg/l for arsenic and selenium, respectively. Measurements of pH shall be reported to the nearest 1/10 standard unit.

B. The determination of compliance shall be based on sampling Well Nos. 2 and 3.

C. The determination of background levels for the parameters specified in subsection (A) shall be defined by sampling Well No. 1.

D. The licensee shall sample for those parameters specified in subsection (A) above at those wells designated in subsections (B) and (C) on a monthly basis for a period of one (1) year and at least twice annually thereafter. The first monthly sample shall be taken within 30 days of the date of this Order. All semiannual samples shall be taken at least four months apart.

E. The licensee shall, within 60 days of collection of the last of the twelve monthly samples, propose for USNRC review and approval in the form of a license amendment background levels for indicator parameters and a statistical procedure for identifying significant changes (95% confidence level) between data from the wells specified in subsections (B) and (C).

F. The licensee shall report the data required by subsection (D) semiannually along with those data required by License Condition No. 18 in accordance to the reporting format, Attachment No. 5 to SUA-1358, "Sample Format for Reporting Detection Monitoring Data." These monitoring requirements are in addition to the requirements specified in License Condition No. 24.

G. The licensee shall report at least annually in accordance to reporting requirements specified in subsection (F) the rate and direction of ground water flow under the tailings impoundment.

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APPENDIX A

TABLES AND FIGURES

Table 1 Prinicipal Parameter Values Used in the Radiological Assessment of the Umetco White Mesa Uranium Mill

Parameter	Value*
General Data	
Average ore grade, % U_3O_8	0.60
Average secular equilibrium ore activity of U-238 and daughters, pCi/gm	1196
Ore processing rate, t/year	730,000
Annual operating time, days/year	365
Recovery rate of ore processing, %	96
Dust/bulk ore activity concentration ratio, Ore Storage and Handling	2.5
Loss of ore dust by truck dumping. lb/ton	0.002+
Loss of oredust by ore pad handling machinery, lb/ton	0.02+
Loss of ore dust by ore load to grizzly and hopper, lb/ton	0.002+
Specific radon flux factor from ore storage, pCi/m²-sec per pCi/gm Ra-226	1.0
Area of ore pad, acres	6
Reduction factor due to spraying and wetting, %	20
Crushing, Grinding, Screening	
Uncontrolled particulate release from crushing, grinding and screening, lb/ton	0.16+
Control efficiency for releases from crushing, grinding and screening, %	95
Fraction of radon content in bulk ore released from crushing, grinding and screening, %	20

See footnotes, last page of table

Table 1 (continued)

Parameter	Value*
Yellowcake Drying and Packaging	
Annual yellowcake production rate, t/yr	4380
Product purity, % U_3O_8	93
Annual U_3O_8 production rate, t/yr	4073
Fraction of U_3O_8 production lost to atmosphere, %	0.1%#
Ratio of Ra-226 or Pb-210 to U-238 concentration in yellowcake stack effluent	0.001
Ratio of Th-230 to U-238 concentration in yellowcake stack effluent	0.005
Radon release rate from yellowcake stack	negligible
Tailings Management Operations	
Total tailings area, m^2	534,200
Dusting rate from exposed beach, gm/m^2-year	2489
Specific radon flux from exposed beach, pCi/m^2-sec per pCi/gm Ra-226	1.0
Dust/tails activity concentration ratios	2.5
Activity in homogeneous solid tailings for:	
U-238 (pCi/gm)	47.8
Th-230	1190
Ra-226	1195
Pb-210	1195
Dusting reduction factor due to water cover and wetting of exposed sands, %	50

See footnotes, last page of table.

Table 1 (continued)

*These values were selected by the NRC staff for use in its radiological assessment of the White Mesa facility. They represent conservative selections from ranges of potential values in instances where available data have been insufficient and/or not specific.

+Values based on recommendations in Colorado Department of Health, Fugitive Emission Factors Worksheet (draft) of Air Pollution Control Division.

#The rationale for this figure is presented on page G-6 of the "Final Generic Environmental Impact Statement on Uranium Milling" (NUREG-0706).

Table 2 Estimated Annual Airborne Releases of Radioactive Materials from the Umetco White Mesa Uranium Mill in the Final Year of Operation under the Renewal*

	Estimated Releases (Curies/Year)+				
Source Description	U-238	Th-230	Ra-226	Pb-210	Rn-222
Ore Delivery	1.30E-3	1.30E-3	1.30E-3	1.30E-3	7.93E+1
Crushing	7.00E-4	7.00E-4	7.00E-4	7.00E-4	3.26E-1
Blowing Ore	7.00E-4	7.00E-4	7.00E-4	7.00E-4	5.15E+2
Grizzly	7.00E-4	7.00E-5	7.00E-4	7.00E-4	7.93E+1
Yellowcake Stack	4.00E-2	2.00E-4	4.00E-5	4.00E-5	0
Evaporation Pond	1.10E-3	2.65E-2	2.66E-2	2.66E-2	6.72E+1
Tailings Cell 2	1.80E-3	4.20E-2	4.20E-2	4.20E-2	2.42E+3
Tailings Cell 3	1.80E-3	4.20E-2	4.20E-2	4.20E-2	2.42E+3

*Releases of all other radionuclides in the U-238 decay series are also included in the radiological impact analysis. These releases are assumed to be identical to those presented here for parent nuclides. For instance, the release rate of U-234 is taken to be identical to that for U-238. Release rates of Pb-210 and Po-210 are assumed equal to that given for Ra-226.

+Releases are estimated on the basis of parameters as displayed in Table 1.

#Releases from the tailings impoundment reflect the configuration as proposed for the final year of operations.

Table 3 Annual Dose Commitments to Individuals in the Vicinity of the Umetco White Mesa Uranium Mill

Location	Exposure Pathway	Annual Dose Commitment,* mrem/year Whole Body	Bone	Lung	Bronchial Epithelium
White Mesa Reservation 5.6 km SE Nearest Resident	Inhalation+	1.69E-2#	4.57E-1	6.63E-1	2.47E+1
	External ground	5.11E-2	5.11E-2	5.11E-2	-
	External cloud	3.22E-1	3.22E-1	3.22E-1	-
	Meat & Vegetable ingestion§	5.57E-2	6.86E-1	5.57E-2	-
Total		4.46E-1	1.52E+0	1.09E+0	2.47E+1
Airport 5.7 km NE Nearest resident in prevailing wind direction	Inhalation	1.57E-2	4.17E-1	6.44E-1	1.09E+1
	External ground	5.73E-2	5.73E-2	5.73E-2	-
	External cloud	1.37E-1	1.37E-1	1.37E-1	-
Total		2.10E-1	6.11E-1	8.38E-1	1.09E+1
Blanding 9.95 km NE	Inhalation	7.86E-3	2.12E-1	3.03E-1	-
	External ground	2.59E-2	2.59E-2	2.59E-2	-
	External cloud	9.08E-2	9.08E-2	9.08E-2	-
	Meat & Vegetable ingestion	3.02E-2	3.73E-1	3.02E-2	-
Total		1.55E-1	7.02E-1	4.50E-1	1.09E+1

*Dose commitments are integrated over a 50-year period from one year of exposure.

+Doses to the whole body, lungs, and bone are those resulting from the inhalation of particulates of U-238, U-234, Th-230, Ra-226, Pb-210 and Po-210. Doses to the bronchial epithelium are those resulting from the inhalation of radon daughters.

#Read as 1.69 x 10^{-2} or 0.0169.

§Ingestion impacts result from the assumed consumption of meat from cattle grazed within 1 km of the mill center.

Table 4 Comparison of Annual Dose Commitments to Individuals with EPA Radiation Protection Standards (40 CFR 190)*

Location	Exposure Pathway	Annual Dose Commitment,* mrem/year Body	Bone	Average Lung
EPA limits (40 CFR 190)		25.0	25.0	25.0
1. White Mesa Reserv. 5.6 km SE Nearest resident	Inhalation	1.60E-2	4.30E-1	6.56E-1
	External	1.13E-3	1.13E-3	1.13E-3
	Meat & Vegetable ingestion+	5.47E-2	6.61E-1	5.47E-2
	Total	7.18E-2	1.092E+0	7.12E-1
	Fraction of limit	2.90E-3	4.37E-2	2.85E-2
2. Airport 5.7 km NE Nearest resident in prevailing wind	Inhalation	1.53E-2	4.03E-1	6.40E-1
	External	1.36E-3	1.36E-3	1.36E-3
	Total	1.67E-2	4.04E-1	6.41E-1
	Fraction of limit	7.00E-4	1.62E-2	2.57E-2
3. Blanding 9.95 km NE	Inhalation	7.28E-3	1.94E-1	2.98E-1
	External	5.95E-4	5.98E-4	5.98E-4
	Meat & Vegetable ingestion+	2.95E-2	5.50E-1	3.28E-1
	Total	3.73E-2	5.50E-1	3.28E-1
	Fraction of limit	1.50E-3	2.20E-2	1.31E-2

*40 CFR Part 190 specifically excludes any dose commitments arising from the release of radon and its daughters.

+Meat ingestion impacts result from the assumed consumption of meat from cattle grazed within 1 km of the mill center.

Table 5 Annual 100-year Environmental Dose Commitments to Regional Population Within 80-km Radius of the Umetco White Mesa Uranium Mill

	Annual Environmental Dose Commitments (EDC), person-rem/Year*			
Exposure Pathway	Whole Body	Bone	Lung	Bronchial Epithelium+
Inhalation	4.62E-2#	1.25E+0	1.715E+0	4.272E+1
External ground	1.236E+0	1.236E+0	1.236E+0	-
External cloud	6.33E-1	6.335E-1	6.335E-1	-
Vegetable ingestion	2.041E-1	2.970E+0	2.041E-1	-
Meat ingestion	9.985E-3	1.526E-1	9.985E-3	-
Milk ingestion	1.794E-2	1.951E-1	1.794E-2	-
TOTAL	2.148E+0	6.443E+0	3.817E+0	4.272E+1
Estimated population dose from natural background§	1.325E+3	1.659E+3	1.33E+3	5.048E+3
Ratio of total EDC to background population dose	0.0016	0.0039	0.0029	0.0085

*Doses to the whole body, lung, and bone are those resulting from the releases of particulates of U-238, U-234, Th-230, Ra-226, and Pb-210.

+Inhalation doses to the bronchial epithelium are those resulting from the inhalation of radon daughters.

#Read as 4.62×10^{-2} or 0.0462

§Background doses are based on the regional population size of 9,015 and natural background organ doses as follows:

Whole body - 147 mrem/yr
Bone - 184 mrem/yr
Lung - 148 mrem/yr
Bronchial epithelium - 560 mrem/yr

Source: G. L. Montet et al., "Description of United States Uranium Resource Areas, a Supplement to the Generic Environmental Impact Statement on Uranium Milling," Report NUREG/CR-0597, ANL/ES-75, prepared by Argonne National Laboratory for the U.S. Nuclear Regulatory Commission, June 1979. The staff assumes the population dose due to background is equivalent to the general background dose for the Wyoming Basin.

Table 6 Total Environmental Dose Commitments (EDC) through the Renewal Period of the Umetco White Mesa Uranium Mill

	EDC to each organ, person-rem			
	Whole Body	Bone	Lung	Bronchial Epithelium
EDCs received by population within 80 Km of mill	2.148E+0	6.443E+0	3.817E+0	4.272E+1[+]
EDCs received by population beyond 80 Km of mill	5.169E+3	6.944E+4	1.100E+3	3.134E+4
Total EDCs received by continental population	5.172E+3	6.945E+4	1.104E+3	3.138E+4
Fraction of background#	2.100E-4	2.820E-3	4.500E-5	2.560E-4

*Total EDCs shown are the combined result of operational releases for the entire duration of 6.0 years (1985-1991).

+The notation 4.272E+1 denotes 4.272×10^1 or 42.72.

#Background values estimated on the basis of year 1991, a continental population of 245.5 million persons, each person receiving 100 millirem/year to the whole body, bone, and lung and 500 millirem/year to the bronchial epithelium.

Table 7 Comparison of Predicted Air Concentration During the Final Year of Mill Operation with 10 CFR 20 Limits for Selected Unrestricted Areas

	Predicted Air Concentrations, pCi/m³							
	U-238	U-234	Th-230	Ra-226	RN-222(WL)*	Pb-210	Bi-210	Po-210
NORTH SITE BOUNDARY								
CONC., PCI/M3	3.59E-02#	3.59E-02	5.29E-03	5.16E-03	1.39E-03	5.16E-03	5.14E-03	5.14E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	7.18E-03	8.98E-03	6.62E-02	2.58E-03	4.19E-02	1.29E-03	2.57E-05	7.35E-04
Sum of fractions equals 1.29E-01								
SOUTH SITE BOUNDARY								
CONC., PCI/M3	1.36E-02	1.36E-02	1.15E-02	1.15E-02	3.55E-03	1.15E-02	1.15E-02	1.15E-02
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	2.71E-03	3.39E-03	1.44E-01	5.75E-03	1.07E-01	2.87E-03	5.73E-05	1.64E-03
Sum of fractions equals 2.67E-01								
EAST SITE BOUNDARY								
CONC., PCI/M3	8.61E-03	8.61E-03	3.12E-03	3.09E-03	1.04E-03	3.09E-03	3.08E-03	3.08E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	1.72E-03	2.15E-03	3.90E-02	1.54E-03	3.12E-02	7.73E-04	1.54E-05	4.40E-04
Sum of fractions equals 7.69-02								
WEST SITE BOUNDARY								
CONC., PCI/M3	6.13E-04	6.13E-04	1.08E-03	1.08E-03	4.95E-04	1.09E-03	1.08E-03	1.08E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	1.23E-04	1.53E-04	1.35E-04	5.41E-04	1.49E-02	2.72E-04	5.40E-06	1.54E-04
Sum of fractions equals 2.97E-02								
NORTHEAST SITE BOUNDARY								
CONC., PCI/M3	7.34E-03	7.34E-03	2.64E-03	2.62E-03	9.65E-04	2.62E-03	2.61E-03	2.61E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	1.47E-03	1.83E-03	3.30E-02	1.31E-03	2.90E-02	6.56E-04	1.31E-05	3.73E-04
Sum of fractions equals 6.77E-02								

See footnotes, last page of table

Table 7 (Continued)

	Predicted Air Concentrations, pCi/m³							
	U-238	U-234	Th-230	Ra-226	RN-222(WL)*	Pb-210	Bi-210	Po-210
SOUTHWEST SITE BOUNDARY								
CONC., PCI/M3	9.44E-04	9.44E-04	2.09E-03	2.09E-03	7.73E-04	2.10E-03	2.09E-03	2.09E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	1.89E-04	2.36E-04	2.62E-02	1.05E-03	2.32E-02	5.24E-04	1.04E-05	2.98E-04
Sum of fractions equals 5.17E-02								
SOUTHEAST SITE BOUNDARY								
CONC., PCI/M3	3.88E-03	3.88E-03	2.38E-03	2.37E-03	1.31E-03	2.38E-03	2.36E-03	2.36E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	7.77E-04	9.71E-04	2.97E-02	1.18E-03	3.94E-02	5.94E-04	1.18E-05	3.37E-04
Sum of fractions equals 7.30E-02								
NORTHWEST SITE BOUNDARY								
CONC., PCI/M3	2.69E-02	2.69E-03	6.59E-03	6.49E-03	1.45E-03	6.49E-03	6.48E-03	6.48E-03
MPC, PCI/M3	5.00E+00	4.00E+00	8.00E-02	2.00E+00	3.33E-02	4.00E+00	2.00E+02	7.00E+00
FRACTION OF MPC	5.38E-03	6.73E-03	8.24E-02	3.25E-03	4.36E-02	1.62E-03	3.24E-05	9.25E-04
Sum of fractions equals 1.44E-01								

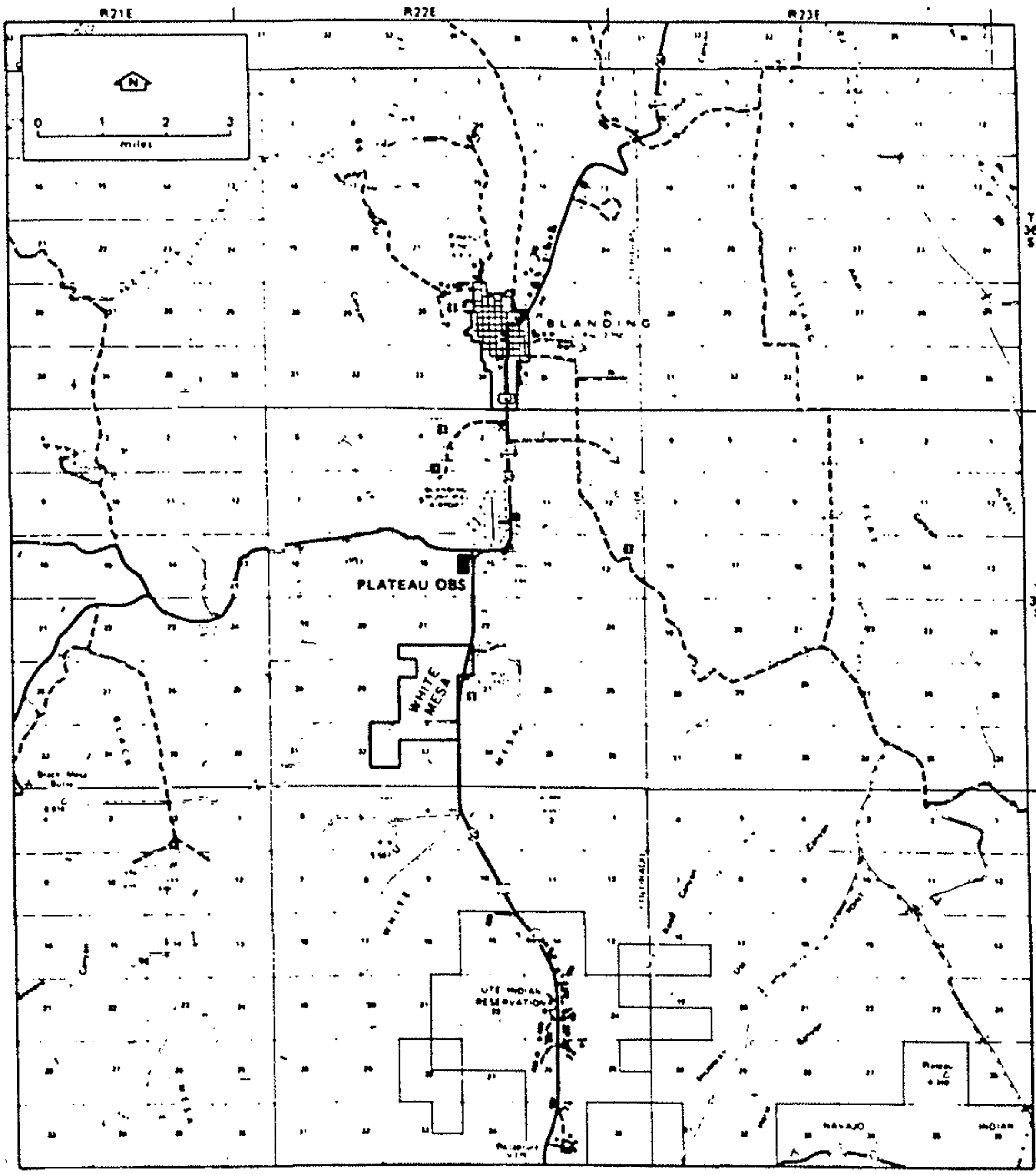
*WL denotes "working level." A one-WL concentration is defined to be any combination of air concentrations of the short lived Rn-222 daughters Po-218, Pb-214, Bi-214, and Po-214 that, in one liter of air, will yield a total of 1.3×10^5 Mev of alpha particle energy in their complete decay to Pb-210. Predicted values given for outdoor air are those calculated on the basis of actual ingrowth from released Rn-222.

+Values given are from 10 CFR Part 20, Appendix B, Table II, Col. 1.

#The notation 3.59E-02 denotes 3.59×10^{-2} or 0.0359

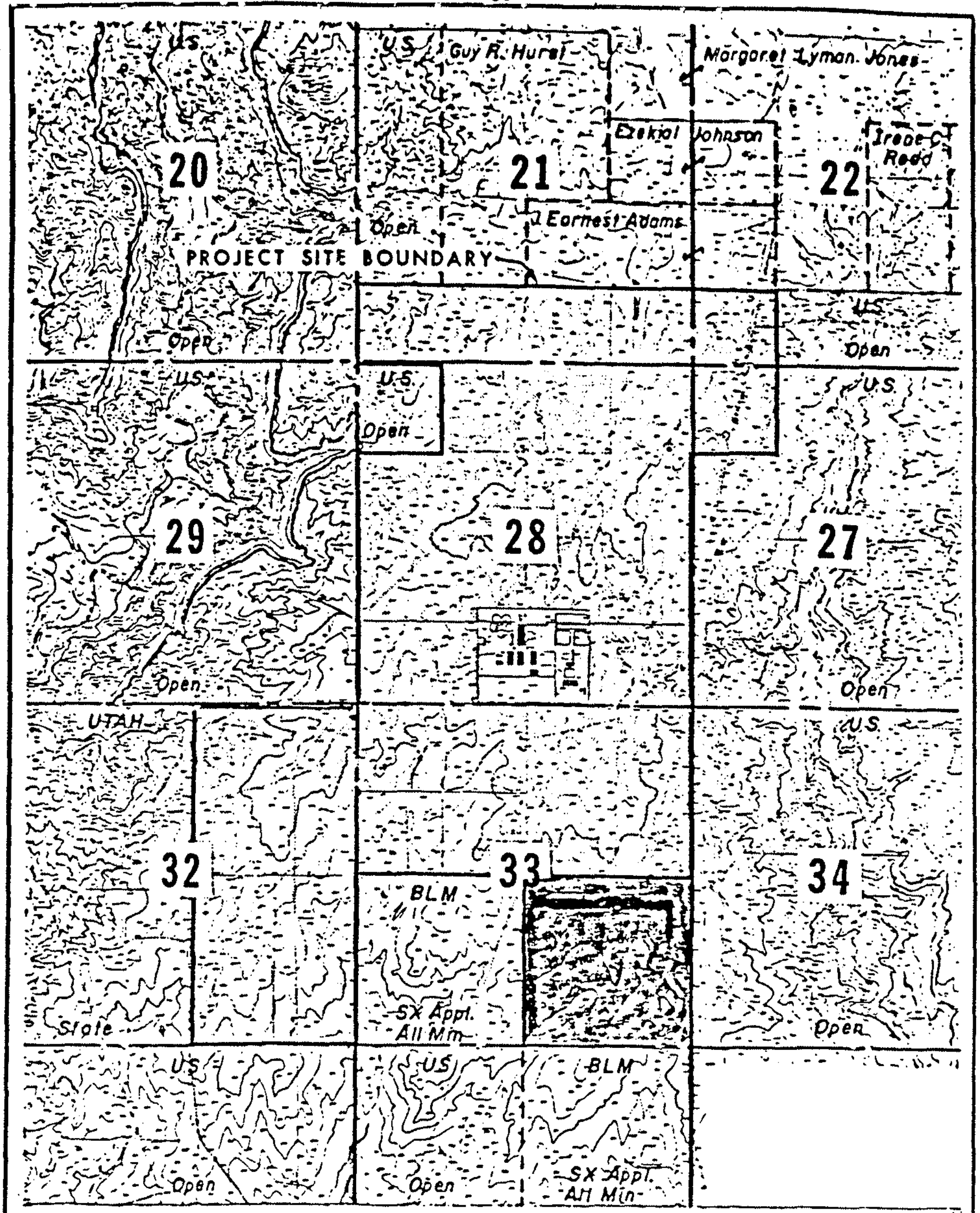
§Compliance with 10 CFR Part 20 is not achieved if the sum of the fractions is greater than 1. That is, if radionuclides A, B, and C are present in concentrations C_A, C_B, C_C and if the applicable maximum permissible concentrations (MPCs) are MPC_A, MPC_B, and MPC_C, respectively, then the concentrations shall be limited so that the following relationship exists:

$$(C_A/MPC_A) + (C_B/MPC_B) + (C_C/MPC_C) \leq 1$$



Location of the site of the White Mesa Uranium Project [OBS = ore buying station]. Source: Plateau Resources, Ltd., *Application for a Source Material License for the Blanding Ore Buying Station*, Grand Junction, Colo., Apr. 3, 1978, Fig. 2.1-2.

FIGURE 1



PROJECT SITE MAP

(TOWNSHIP 37 SOUTH RANGE 22 EAST)

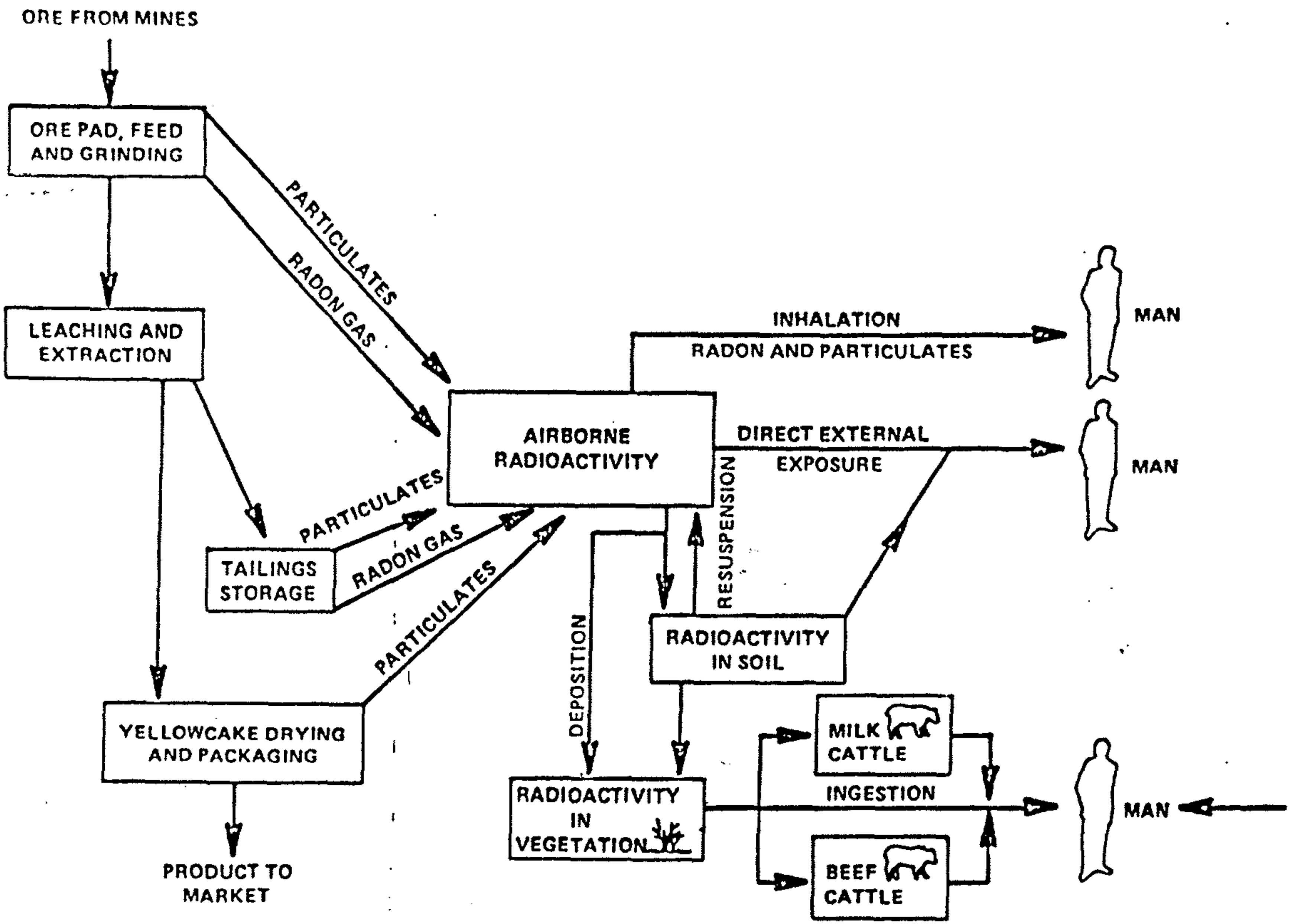


Figure 3 Sources of Radioactive Effluents from the EXXON Highland Mill and Exposure Pathways to Man

FIGURE 3

APPENDIX B

DETAILED RADIOLOGICAL ASSESSMENT

Appendix B

DETAILED RADIOLOGICAL ASSESSMENT

This assessment describes the models, data, and assumptions used by the staff to perform its radiological impact assessment of the Umetco White Mesa Uranium Mill. The primary calculational tool employed is MILDOS,[1] an NRC-modified version of the UDAD (Uranium Dispersion and Dosimetry) computer code originated at Argonne National Laboratory.[2]

B.1 ANNUAL RADIOACTIVE MATERIAL RELEASES

Table 2 lists estimated annual activity releases for the Umetco White Mesa Uranium Mill. All data except for the annual average dusting rate for exposed tailings sands are based on the data and assumptions given in Table 1. This dusting rate is calculated in accordance with the following equation:

$$M = \frac{3.156 \times 10^7}{0.5} \sum_s R_s F_s , \qquad \text{(B-1)}$$

where

F_s = annual average frequency of occurrence of wind speed group s, dimensionless;

R_s = dusting rate for tailings sands at the average wind speed for wind speed group s for particles ≤ 20 µm diam, $g/m^2 \cdot s$;

M = annual dust loss per unit area, $g/m^2 \cdot year$;

3.156×10^7 = number of seconds per year;

0.5 = fraction of total dust loss constituted by particles ≤ 20 µm diameter, dimensionless.[1]

The values of R_s and F_s used by the staff are as given in Table B.1.

The calculated value of the annual dusting rate, M, is 2489 $g/m^2 \cdot year$. Annual curie releases from the tailings pile are then given by the following relationship:

$$S = MA(1 - f_c)f_t(C)\ (2.5 \times 10^{-12}), \qquad \text{(B-2)}$$

where

A = assumed beach area of the pile, m^2;

f_c = fraction of dusting rate controlled by mitigating actions, dimensionless;

Table B.1 Parameter values for calculation of annual dusting rate for exposed tailings sands*

Wind speed group (knots)	Average wind speed (mph)	Dusting rate rate ($g/m^2 \cdot s$)	Annual frequency occurrence
0-3	1.5	0	0
4-6	5.5	0	0
7-10	10.0	3.92E-7†	0.1219
11-16	15.5	9.68E-6	0.0195
17-21	21.5	5.71E-5	0.0035
>21	28.0	2.08E-4	0.1879

*Dusting rate as a function of wind speed is computed by the MILDOS code.[1] Wind speed frequencies obtained from annual joint frequency data presented in Table B.2.

†Read as 3.92×10^{-7}, or .000000392.

ÉGION=WHITE MESA MILL CODE=MILDOS,REVO (7/79) DATE= 85/05/31.
ETSET= ONSITE METDATA PAGE NO. 2
JOINT FREQUENCY IN PERCENT, DIRECTION INDICATES WH ERE WIND IS FROM FREQWS= .37367, .29282, .12185, .01950, .00353, .18785

PH	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTALS
STABILITY CLASS 1																	
1.5	.4478	.2171	.3329	.2595	.3329	.3322	.7119	.6898	1.0312	.4212	.8383	.4661	.5680	.2185	.3783	.2321	7.4778
5.5	.1555	.0990	.1555	.0565	.1555	.1131	.4948	.9047	1.5833	1.1733	1.2016	.3958	.4806	.1838	.2969	.1414	7.5913
0.0	.1131	.0990	.0990	0.0000	0.0000	.0141	.0424	.1272	.3817	.6503	.7775	.2120	.2403	.1414	.1979	.1131	3.2090
5.5	.0424	.0141	0.0000	0.0000	.0141	.0141	0.0000	0.0000	0.0000	.0565	.0990	.0424	.0707	.0283	.0141	.0141	.4098
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.0	.1284	.0430	.1710	.1428	.1996	.1574	.2583	.3734	.3329	.2609	.2157	.1008	.0565	.1431	.0431	.1002	2.7271
LL	.8872	.4722	.7584	.4588	.7021	.6309	1.5074	2.0951	3.3291	2.5622	3.1321	1.2171	1.4161	.7151	.9303	.6009	21.4150
STABILITY CLASS 2																	
1.5	.0565	.0565	.0565	.0990	.0848	.1555	.3817	.5937	.9471	.8058	.3817	.1979	.1131	.1414	.0707	.0990	4.2409
5.5	.0848	.0484	.0424	.0141	.0283	.0848	.0990	.1414	.4806	1.1309	.8058	.3393	.1696	.0565	.1696	.2120	3.9075
0.0	.0282	0.0000	0.0000	.0141	.0141	0.0000	0.0000	.0424	.1555	.2403	.3817	.3110	.1131	.0565	.0707	.0848	1.5124
5.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0282	.0141	0.0000	0.0000	0.0000	0.0000	0.0000	.0283	.0706
1.5	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.0	.0990	.0424	.1555	0.0000	.0424	.0282	.0565	.0848	.1131	.1272	.0565	.0283	.0565	.0141	0.0000	.0141	.9186
LL	.2685	.1473	.2544	.1272	.1696	.2685	.5372	.8623	1.7245	2.3183	1.6257	.8765	.4523	.2685	.3110	.4382	10.6500
STABILITY CLASS 3																	
1.5	.1555	.1414	.0565	.0283	.0990	.0848	.2262	.3251	.6644	.3958	.1555	.0424	.1131	.0707	.1838	.0848	2.8273
5.5	.0565	.0141	.0141	.0141	.0141	.0707	.0848	.2262	.4524	.5230	.2262	.1272	.1272	.0565	.0990	.0565	2.1626
0.0	.0848	0.0000	0.0000	0.0000	0.0000	.0141	.0141	0.0000	.1131	.1979	.2545	.1272	.2545	.0565	.1838	.0848	1.3853
5.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0141	.0424	.0283	.0283	.0141	0.0000	0.0000	.0282	.1554
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0141	0.0000	0.0000	0.0000	.0141	0.0000	0.0000	0.0000	.0282
8.0	.4665	.7775	.4948	.1272	.1131	.0283	.0565	.1131	.1131	.0848	.1272	.0424	.0848	.0283	.0848	.0707	2.8131
LL	.7633	.9330	.5654	.1696	.2262	.1979	.3816	.6644	1.3712	1.2439	.7917	.3675	.6078	.2120	.5514	.3250	9.3719
STABILITY CLASS 4																	
1.5	1.5126	1.7246	1.0319	.1696	.1838	.0707	.2262	.3534	.4948	.4382	.3534	.2686	.2262	.2403	.3817	.5513	8.2273
5.5	1.1592	.6079	.6361	.0848	.2120	.0848	.2686	.1979	.5513	.4806	.6220	.4100	.3251	.5372	.6785	.9330	7.7890
0.0	.1555	.1414	.0282	.0848	.0141	.0283	.1979	.0424	.2120	.3958	.2545	.3675	.3110	.0565	.3817	.3393	3.0109
5.5	.0565	0.0000	.0141	0.0000	0.0000	0.0000	.0141	0.0000	.0565	.0848	.1131	.0707	.1272	0.0000	.0565	.0707	.6642
1.5	.0141	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0283	.0424	.0848	.0283	0.0000	0.0000	0.0000	0.0000	.1979
8.0	.7257	.7107	.5811	.0567	.0142	.0142	.1135	.0428	.1276	.0143	.0710	.0284	.1559	.0709	.1418	.1420	3.0108
LL	3.6236	3.1846	2.2914	.3959	.4241	.1980	.8203	.6365	1.4705	1.4561	1.4988	1.1735	1.1454	.9049	1.6402	2.0363	22.9001
STABILITY CLASS 5																	
1.5	3.8309	2.9545	.9047	.1131	.0424	.0424	.2686	.3534	.2545	.1272	.2686	.0990	.2120	.1838	.3110	.5089	10.4750
5.5	2.1487	1.3571	.2969	.0424	.0283	.0848	.2969	.0565	.6079	.2969	.3534	.2969	.2403	.2686	.6503	.7068	7.7327
0.0	.1272	.1696	.2545	.0283	0.0000	.0141	.0283	.0283	.1979	.4100	.3817	.1555	.0990	.0990	.6079	.4665	3.0678
5.5	0.0000	.0424	.0848	0.0000	0.0000	0.0000	.0141	0.0000	.0141	.0848	.0990	.0424	.0565	0.0000	.1272	.0848	.6501
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0707	.0283	.0141	.0141	0.0000	0.0000	0.0000	.1272
8.0	1.4147	.9425	1.0996	.5712	.4985	.2923	.3960	.2070	.3976	.2652	.3685	.1921	.5272	.3261	.9751	.8423	9.3159
LL	7.5215	5.4661	2.6405	.7550	.5692	.4336	1.0039	.6452	1.4720	1.2548	1.4995	.8000	1.1491	.8775	2.6715	2.6093	31.3687
STABILITY CLASS 6																	
1.5	.6927	.4382	.3393	.1555	.1555	.0565	.1272	.1272	.1838	.1272	.1838	.1131	.1313	.2272	.5655	.4948	4.1188
5.5	.0990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0990
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0	0.C000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L	.7917	.4382	.3393	.1555	.1555	.0565	.1272	.1272	.1838	.1272	.1838	.1131	.1313	.2272	.5655	.4948	4.2178
L	13.8558	10.6414	6.8494	2.0620	2.2467	1.7854	4.3776	5.0307	9.5511	8.9625	8.7316	4.5477	4.9020	3.2052	6.6699	6.5045	99.9235

f_t = fraction of ore content of particular nuclide present in the tailings;

S = annual release for the particular beach area, Ci/year;

C = assumed raw ore activity, pCi/g;

2.5 = dust-to-tails activity ratio;

10^{-12} = Ci/pCi.

The staff considered one evaporative pond and four tailings impoundments increasing in beach area from startup in 1985.8. The total impoundment is estimated to have a maximum capacity of 534,200 m². However, during the operational phase of the mill's life, 80% of the total area is assumed to be available for dusting. In the final year of the renewal, 427,360 m² are assumed to be available for dusting; the remainder of the tailings are assumed to be covered by tailings liquid or controlled by water spraying.

Dust losses from the ore storage piles were estimated by assuming that they would be about 10% of those from an equivalent area of tailings beach.

B.2 ATMOSPHERIC TRANSPORT

The staff analysis of offsite air concentrations of radioactive materials has been based on two years of meteorological data collected at the White Mesa uranium mill site from June 1981 to June 1982. The collected meteorological data are entered into the MILDOS code as input in the form of a joint frequency distribution by stability class, wind speed group, and direction. The joint frequency data employed by the staff for this analysis are presented in Table B.2.

The dispersion model employed by the MILDOS code is the basic straight-line Gaussian plume model. Ground-level, sector-average concentrations are computed using this model and are corrected for decay and ingrowth in transit (for radon-222 and daughters) and for depletion caused by deposition losses (for particulate matter). Area sources are treated using a virtual point source technique. Resuspension into the air of particulate material initially deposited on ground surfaces is computed using a resuspension factor that depends on the age of the deposited material and its particle size. For the isotopes of concern here, the total air concentration including resuspension is about 1.6 times the ordinary air concentration.

The assumed particle size distribution, particle density, and deposition velocities for each source are presented in Table B.3.

Table B.3. Physical characteristics assumed for particulate material releases

Activity source	Diameter (μm)	Density (g/cm^3)	Deposition Velocity (cm/s)	AMAD* (μm)
Crusher dusts	1.0	2.4	1.0	1.55
Yellowcake dusts	1.0	8.9	1.0	2.98
Tailings, ore pile dusts				
30%	5.0	2.4	1.0	7.75
70%	35.0	2.4	8.8	54.2
Ingrown radon daughters	0	1.0	0.3	0.3

*Aerodynamic equivalent diameter, used in calculating inhalation doses.[1]

B.3 CONCENTRATION IN ENVIRONMENTAL MEDIA

Information provided below describes the methods and data used by the staff to determine the concentrations of radioactive materials in the environmental media of concern in the vicinity of the site. These include concentrations in the air (for inhalation and direct external exposure), on the ground (for direct external exposure), and in meat and vegetables (for ingestion exposure). Concentration values are computed explicitly by the MILDOS code for U-238, Th-230, Ra-226, Rn-222 (air only), and Pb-210. Concentrations of Th-234, Pa-234, and U-234 are assumed to equal that of U-238. Concentrations of Bi-210 and Po-210 are assumed to equal that of Pb-210.

B.3.1 Air concentrations

Ordinary, direct air concentrations are computed by the MILDOS code for each receptor location from each activity source by particle size (for particulates). Direct air concentrations computed by MILDOS include depletion by deposition (particulates) or the effects of ingrowth and decay in transit (radon and daughters). To compute inhalation doses, the total air concentration of each isotope at each location, as a function of particle size, is computed as the sum of the direct air concentration and the resuspended air concentration:

$$C_{aip}(t) = C_{aipd} + C_{aipr}(t), \qquad \text{(B-3)}$$

where

$C_{aip}(t)$ = total air concentration of isotope i, particle size p, at time t, pCi/m^3;

C_{aipd} = direct air concentration of isotope i, particle size p, for the time constant, pCi/m³;

$C_{aipr}(t)$ = resuspended air concentration of isotope i, particle size p, at time t, pCi/m³.

The resuspended air concentration is computed using a time-dependent resuspension factor, $R_p(t)$, defined by

$$R_p(t) = (1/V_p)10^{-5}\ e^{-\lambda_R t} \qquad \text{for } t \le 1.82 \text{ year}$$

$$= (1/V_p)10^{-9} \qquad \text{for } t > 1.83 \text{ year}\ , \qquad \text{(B-4)}$$

where

$R_p(t)$ = ratio of the resuspended air concentration to the ground concentration, for a ground concentration of age t years, of particle size p, m^{-1};

V_p = deposition velocity of particle size p, cm/s;

λ_R = assumed decay constant of the resuspension factor (equivalent to a 50-d half-life), 5.06 years;

10^{-5} = initial value of the resuspension factor (for particles with a deposition velocity of 1 cm/s), m^{-1};

10^{-9} = terminal value of the resuspension factor (for particles with a deposition velocity of 1 cm/s), m^{-1};

1.82 = time required to reach the terminal resuspension factor, years.

The basic formulation of the above expression for the resuspension factor, the initial and final values, and the assigned decay constant derive from experimental observations.[4] The inverse relationship to deposition velocity eliminates mass balance problems involving resuspension of more than 100% of the initial ground deposition for the 35-μm particle size (see Table B.3). Based on this formulation, the resuspended air concentration is given by

$$C_{aipr}(t) = 0.01\ C_{aipd} \times 10^{-5}\ \frac{1 - \exp[-(\lambda_i^* + \lambda_R)\ (t - a)]}{(\lambda_i^* + \lambda_R)}$$

$$+ 10^{-4}\delta(t)\ \frac{\exp[-\lambda_i^*(t - a)] - \exp(-\lambda_i^* t)}{\lambda_i^*}\ (3.156 \times 10^7), \qquad \text{(B-5)}$$

where

$a = (t - 1.82)$ if $t \leq 1.82$, years;

$\delta(t) = 0$ if $t < 1.82$ and is unity otherwise, dimensionless;

$\lambda_i^* =$ effective decay constant for isotope i on soil, year $^{-1}$;

0.01 = deposition velocity for the particle size for which the initial resuspension factor value is 10^{-5} per meter, m/s;

3.156×10^7 = s/year.

Total air concentrations are computed using Eqs. B-3 and B-5 for all particulate effluents. Radon daughters that grow in from released radon are not depleted because of deposition losses and are therefore not assumed to resuspend.

B.3.2 Ground concentrations

Radionuclide ground concentrations are computed from the calculated airborne particulate concentrations arising directly from onsite sources (not including air concentrations resulting from resuspension). Resuspended particulate concentrations are not considered for evaluating ground concentrations. The direct deposition rate of radionuclide i is calculated using the following relationship:

$$D_{di} = \sum_p C_{adip} V_p , \qquad \text{(B-6)}$$

where

C_{adip} = direct air concentration of radionuclide i, particle size p, pCi/m^3;

D_{di} = resulting direct deposition rate of radionuclide i, $pCi/m^2 \cdot s$;

V_p = deposition velocity of particle size p, m/s (see ref. 4).

The concentration of radionuclide i on a ground surface resulting from constant deposition at the rate D_{di} over time interval t is obtained from

$$C_{gi}(t) = D_{di} \frac{1 - \exp(-\lambda_i + \lambda_e)t}{\lambda_i + \lambda_e} , \qquad \text{(B-7)}$$

where

$C_{gi}(t)$ = ground surface concentration of radionuclide i at time t, pCi/m^2;

t = time interval over which deposition has occurred, s;

λ_e = assumed rate constant for environmental loss, s^{-1};

λ_i = radioactive decay constant[5] for radionuclide i, s^{-1}.

The environmental loss constant λe corresponds to an assumed half-time for loss of environmental availability of 50 years.[4] This parameter accounts for downward migration in soil and loss of availability caused by chemical binding. It is assumed to apply to all radionuclides deposited on the ground.

Ground concentrations are explicitly computed only for U-238, Th-230, Ra-226, and Pb-210. For all other radionuclides, the ground concentration is assumed equal to that of the first parent radionuclide for which the ground concentration is explicitly calculated. For lead-210, ingrowth from deposited radium-226 can be significant. The concentration of lead-210 on the ground caused by radium-226 deposition is calculated by the staff using the standard Bateman formulation and assuming that radium-226 decays directly to lead-210. If i = 6 for radium-226 and i = 12 for lead-210 (ref. 1), the following equation is obtained:

$$C_{g12}(\text{pb} \leftarrow \text{Ra}) = \frac{\lambda_{12} D_{d6}}{\lambda_6^*} \left[\frac{1 - \exp(-\lambda_{12}^* t)}{\lambda_{12}^*} + \frac{\exp(-\lambda_6^* t) - \exp(-\lambda_{12}^* t)}{\lambda_6^* - \lambda_{12}^*} \right] , \quad \text{(B-8)}$$

where

$C_{g12}(\text{Pb} \leftarrow \text{Ra})$ = incremental lead-210 ground concentration resulting from radium-226 deposition, pCi/m^2;

λ_n^* = effective rate constant for loss by radioactive decay and migration of a ground-deposited radionuclide and $= \lambda_n + \lambda_e$, s^{-1}.

B.3.3 Vegetation concentrations

Vegetation concentrations are derived from ground concentrations and total deposition rates. Total deposition rates are given by the following summation:

$$D_i = \sum_p C_{aip} V_p , \quad \text{(B-9)}$$

where D_i is the total deposition rate, including deposition of resuspended activity, of radionuclide i, $pCi/m^2 \cdot s$.

Concentrations of released particulate materials can be environmentally transferred to the edible portions of vegetables or to hay or pasture grass consumed by animals by two mechanisms - direct foliar retention and root uptake. Five categories of vegetation are treated by the staff: edible above ground vegetables, potatoes, other edible below ground vegetables, pasture grass, and hay. Vegetation concentrations are computed using the following equation:

$$C_{vi} = D_i E_r E_v \frac{1 - \exp(-\lambda_w t_v)}{Y_v \lambda_w} + C_{gi}(B_{vi}/P) , \qquad \text{(B-10)}$$

where

B_{vi} = soil-to-plant transfer factor for isotope i, vegetation type v, dimensionless;

C_{vi} = resulting concentration of isotope i, in vegetation v, pCi/kg;

E_v = fraction of foliar deposition reaching edible portions of vegetation v, dimensionless;

E_r = fraction of total deposition retained on plant surfaces, 0.2, dimensionless;

P = assumed areal soil density for surface mixing, 240 kg/m^2;

t_v = assumed duration of exposure while growing for vegetation v, s;

Y_v = assumed yield density of vegetation v, kg/m^2;

λ_w = decay constant accounting for weathering losses (equivalent to a 14-d half-life), 5.73 x 10^{-7} per second.

The value of Ev is assumed to be 1.0 for all above ground vegetation and 0.1 for all below ground vegetables.[6] The value of t_v is taken to be 60 d, except for pasture grass, where a value of 30 d is assumed. The yield density, Y_v, is taken to be 2.0 kg/m^2, except for pasture grass, where a value of 0.75 kg/m^2 is applied. Values of the soil to plant transfer coefficients, B_{vi}, are provided in Table B.4.

B.3.4 Meat and milk concentrations

Radioactive materials can be deposited on grasses, hay, or silage, which are eaten by meat animals, which are, in turn, eaten by man. It has been assumed that meat animals obtain 75% of their feed requirements by open grazing and by eating nonlocally grown stored feed for the remaining portion of their feed requirement. The equation used to estimate meat concentrations is

$$C_{bi} = QF_{bi}(0.80C_{pgi} + 0.0C_{hi}), \qquad \text{(B-11)}$$

Table B.4 Environmental transfer coefficients

Material	U	Th	Ra	Pb
Plant/soil, B_{vi}				
Edible above ground	2.5E-3*	4.2E-3	1.4E-2	4.0E-3
Potatoes	2.5E-3	4.2E-3	3.0E-3	4.0E-3
Other below ground	2.5E-3	4.2E-3	1.4E-2	4.0E-3
Pasture grass	2.5E-3	4.2E-3	1.8E-2	2.8E-2
Stored feed (hay)	2.5E-3	4.2E-3	8.2E-2	3.6E-2
Beef/feed, F_{bi}, pCi/kg per pCi/d	3.4E-4	2.0E-4	5.1E-4	7.1E-4

*Read as 2.5×10^{-3}, or .0025.

Source: U.S. Nuclear Regulatory Commission, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Operations," Report Task RH 802-4, Washington, D.C., May 1979.

where

C_{pgi} = concentration of isotope i in pasture grass, pCi/kg;

C_{hi} = concentration of isotope i in hay (or other stored feed), pCi/kg;

C_{bi} = resulting concentration of isotope i in meat, pCi/kg;

F_{bi} = feed-to-meat transfer factor for isotope i, pCi/kg per pCi/d (see Table B.4);

Q = assumed feed ingestion rate, 50 kg/d;

0.25 = fraction of total annual feed requirement assumed to be satisfied by pasture grass;

0.75 = fraction of the total annual feed requirement assumed to be satisfied by locally grown stored feed (hay).

The above grazing assumptions are also reflected in the following equation for milk concentrations:

$$C_{mi} = QF_{mi}(0.80C_{pgi} + 0.0C_{hi}) , \quad \text{(B-12)}$$

where

C_{mi} = average concentration of isotope i in milk, pCi/L;

F_{mi} = feed-to-milk activity transfer factor for isotope i, pCi/L per pCi/d ingested (see Table B.4).

B.4 DOSES TO INDIVIDUALS

Doses to individuals have been calculated for inhalation; external exposure to air and ground concentrations; and ingestion of vegetables, meat, and milk. Internal doses are calculated by the staff, using dose conversion factors that yield the 50-year dose commitment; that is, the entire dose insult received over a period of 50 years following either inhalation or ingestion.[2,7] Annual doses given are the 50-year dose commitments resulting from a one-year exposure period. The one-year exposure period was taken to be the final year of mill operation, when environmental concentrations resulting from plant operations are expected to be near their highest level.

B.4.1 Inhalation doses

Inhalation doses have been computed using air concentrations obtained by Eq. B-3 (resuspended air concentrations are included) for particulate materials and the dose conversion factors presented in Table B.5.

Dose to the bronchial epithelium from radon-222 and short-lived daughters were computed based on the assumption of indoor exposure at 100% occupancy. The dose conversion factor for bronchial epithelium exposure from radon-222 derives as follows:

1. 1 pCi/m^3 radon-222 = 5 x 10^{-6} working levels (WL).*

2. Continuous exposure to 1 WL = 25 cumulative working level months (WLM) per year.

3. 1 WLM = 5000 mrem.[8]

Therefore,

$$(1\ \text{pCi/m}^3\ \text{radon-222}) \times 5 \times 10^{-6}\ \frac{\text{WL}}{\text{pCi/m}^3} \times 25\ \frac{\text{WLM}}{\text{WL}} \times 5000\ \frac{\text{millirem}}{\text{WLM}} = 0.625\ \text{millirem},$$

and the radon-222 bronchial epithelium dose conversion factor is taken to be 0.625 millirem per year per pCi/m^3.

*One WL concentration is defined as any combination of short-lived radioactive decay products of radon-222 in 1 L of air that will release 1.3 x 10^5 MeV of alpha particle energy during radioactive decay to lead-210.

Table B.5 Inhalation dose conversion factors. Values are given in millirem per year per pCi/m^3

Organ	U-238	U-234	U-230	Ra-226	Pb-210	Po-210
			Particle size = 0.3 μm			
Whole body					7.46E+0*	1.29E+0
Bone					2.32E+2	5.24E+0
Kidney					1.93E+2	3.87E+1
Liver					5.91E+1	1.15E+1
Mass average lung					6.27E+1	2.66E+2
			Particle size = 1.0 μm, density = 8.9 g/cm^3			
Whole body	9.82E+0	1.12E+1	1.37E+2	3.58E+1	4.66E+0	5.95E+1
Bone	1.66E+2	1.81E+2	4.90E+3	3.58E+2	1.45E+2	2.43E+0
Kidney	3.78E+1	4.30E+1	1.37E+3	1.26E+0	1.21E+2	1.79E+1
Liver	0.	0.	2.82E+2	4.47E-2	3.69E+1	5.34E+0
Mass average lung	1.07E+3	1.21E+3	2.37E+3	4.88E+3	5.69E+2	3.13E+2
			Particle size = 1.0μm, density = 2.4 g/cm^3			
Whole body	4.32E+0	4.92E+0	1.66E+2	3.09E+1	4.36E+0	4.71E-1
Bone	7.92E+1	7.95E+1	5.95E+3	3.09E+2	1.35E+2	1.92E+0
Kidney	1.66E+1	1.89E+1	1.67E+3	1.09E+0	1.13E+2	1.42E+1
Liver	0.	0.	3.43E+2	3.87E-2	3.45E+1	4.22E+0
Mass average lung	1.58E+2	1.80E+2	3.22E+3	6.61E+3	7.72E+3	4.20E+2
			Particle size = 5.0 μm			
Whole body	1.16E+0	1.32E+0	1.01E+2	4.00E+1	4.84E+0	7.10E-1
Bone	1.96E+1	2.14E+1	3.60E+3	4.00E+2	1.50E+2	2.89E+0
Kidney	4.47E+0	5.10E+0	1.00E+3	1.41E+0	1.25E+2	2.13E+1
Liver	0.	0.	2.07E+2	4.97E-2	3.83E+1	6.36E+0
Mass average lung	1.24E+3	1.42E+3	1.38E+3	2.84E+3	3.30E+2	1.88E+2
			Particle size = 35.0 μm			
Whole body	7.92E-1	9.02E-1	5.77E+1	3.90E+1	4.43E+0	7.28E-1
Bone	1.34E+1	1.46E+1	2.07E+3	3.90E+2	1.38E+2	2.96E+0
Kidney	3.05E+0	3.47E+0	5.73E+2	1.38E+0	1.15E+2	2.19E+1
Liver	0.	0.	1.19E+2	4.85E-2	3.51E+1	6.52E+0
Mass average lung	3.33E+2	3.80E+2	3.71E+2	7.64E+2	8.70E+1	5.75E+1

*Read as 7.46 x 10^0, or 7.46.

Sources: M. Momeni et al., "Uranium Dispersion and Dosimetry (UDAD) Code," Report ANL/ES-72, NUREG/CR-0553, Argonne National Laboratory, Chicago, May 1979 and D. R. Kalkwarf, "Solubility Classification of Airborne Products from Uranium Ores and Tailings Piles," Report PNL-2830, NUREG/CR-0530, Pacific Northwest Laboratory, Richland, Wash., January 1979.

B.4.2 External doses

External doses from air and ground concentrations are computed using the dose conversion factors provided in Table B.6.[1] Doses are computed based on 100% occupancy at the particular location. Indoor exposure is assumed to occur 14 h/d at a dose rate of 70% of the outdoor dose rate.

B.4.3 Ingestion doses

Ingestion doses are computed for vegetables and meat (beef and lamb) on the basis of concentrations obtained using Eqs. B-9 through B-12, ingestion rates given in Table B.7, and dose conversion factors given in Table B.8.[1,4] Vegetable ingestion doses were computed assuming an average 50% activity reduction caused by food preparation.[4] Ingestion doses to children and teenagers were computed but were found to be equal to or less than doses to adults.

Table B.6 Dose conversion factors for external exposure

Isotope	Skin	Whole body
	For air concentration doses, millirem per year per pCi/m³	
U-238	1.05E-5*	1.57E-6
Th-234	6.63E-5	5.24E-5
Pa(m)-234	8.57E-5	6.64E-5
U-234	1.36E-5	2.49E-6
Th-230	1.29E-9	3.59E-6
Ra-226	6.00E-5	4.90E-5
Rn-222	3.46E-0	2.83E-6
Po-218	8.18E-7	6.34E-7
Pb-214	2.06E-3	1.67E-3
Bi-214	1.36E-2	1.16E-2
Po-214	9.89E-7	7.66E-7
Pb-210	4.17E-5	1.43E-3
	For ground concentration doses, millirem per year per pCi/m²	
U-238	2.13E-6	3.17E-7
Th-234	2.10E-6	1.66E-6
Pa(m)-234	1.60E-6	1.24E-6
U-234	2.60E-6	4.78E-7
Th-230	2.20E-6	6.12E-7
Ra-226	1.16E-6	9.47E-7
Rn-222	6.15E-8	5.03E-8
Po-218	1.42E-8	1.10E-8
Pb-214	3.89E-5	3.16E-5
Bi-214	2.18E-4	1.85E-4
Po-214	1.72E-8	1.33E-8
Pb-210	6.65E-6	2.27E-6

*Read as 1.05×10^{-5}, or .0000105.

Source: U.S. Nuclear Regulatory Commission, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations," Report Task RH 802-4, Washington, D.C., May 1979.

Table B.7 Assumed food ingestion rates*

	Infant	Child	Teen	Adult
Vegetables, kg/year	-	48	76	105
Edible above ground	-	17	29	40
Potatoes	-	27	42	60
Other below ground	-	3.4	5.0	5.0
Meat (beef, fresh pork, and lamb), kg/year	-	28	45	78
Milk, L/year	208	208	246	130

*Ingestion rates are averages for typical rural farm households. No allowance is credited for portions of year when locally or homegrown food may not be available.

Source: J. F. Fletcher and W. L. Dotson, "HERMES — A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry," Report HEDL-TME-71-168, Hanford Engineering Development Laboratory, Hanford, Wash., December 1971.

Table B.8 Ingestion dose coversion factors, values are in millirem/pCi ingested

		Isotope							
Age Group	Organ	U-238	U-234	Th-234	Th-230	Ra-226	Pb-210	Bi-210	Po-210
Infant	Whole body	3.33E-4*	3.80E-4	2.00E-8	1.06E-4	1.07E-2	2.38E-3	3.58E-7	7.41E-4
	Bone	4.47E-3	4.88E-3	6.92E-7	3.80E-3	9.44E-2	5.28E-2	4.16E-6	3.10E-3
	Liver	0.	0.	3.77E-8	1.90E-4	4.76E-5	1.42E-2	2.68E-5	5.93E-3
	Kidney	9.28E-4	1.06E-3	1.39E-7	9.12E-4	8.72E-4	4.33E-2	2.08E-4	1.26E-2
Child	Whole body	1.94E-4	2.21E-4	9.88E-9	9.91E-5	9.87E-3	2.09E-3	1.69E-7	3.67E-4
	Bone	3.27E-3	3.57E-3	3.42E-7	3.55E-3	8.76E-2	4.75E-2	1.97E-6	1.52E-3
	Liver	0.	0.	1.51E-8	1.78E-4	1.84E-5	1.22E-2	1.02E-5	2.43E-3
	Kidney	5.24E-4	5.98E-4	8.01E-8	8.67E-8	4.88E-4	3.67E-2	1.15E-4	7.56E-3
Teenager	Whole body	6.49E-5	7.39E-5	3.31E-9	6.00E-5	5.00E-3	7.01E-4	5.66E-8	1.23E-4
	Bone	1.09E-3	1.19E-3	1.14E-7	2.16E-3	4.09E-2	1.81E-2	6.59E-7	5.09E-4
	Liver	0.	0.	6.68E-9	1.23E-4	8.13E-6	5.44E-3	4.51E-6	1.07E-3
	Kidney	2.50E-4	2.85E-4	3.81E-8	5.99E-4	2.32E-4	1.72E-2	5.48E-5	3.60E-3
Adult	Whole body	4.54E-5	5.17E-5	2.13E-9	5.70E-5	4.60E-3	5.44E-4	3.96E-8	8.59E-5
	Bone	7.67E-4	8.36E-4	8.01E-8	2.06E-3	4.60E-2	1.53E-2	4.61E-7	3.56E-4
	Liver	0.	0.	4.71E-9	1.17E-4	5.74E-6	4.37E-3	3.18E-6	7.56E-4
	Kidney	1.75E-4	1.99E-4	2.67E-8	5.65E-4	1.63E-4	1.23E-2	3.83E-5	2.52E-3

*Read as 3.33 x 10^{-4} or .000333.

Sources: U.S. Nuclear Regulatory Commission, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations," Report Task RH 802-4, Washington, D.C., May 1979 and G. R. Hoenes and J. K. Soldat, "Age-Specific Radiation Dose Conversion Factors for a One-Year Chronic Intake," Report NUREG-0172, Battelle Pacific Northwest Laboratories, Richland, Washington, November 1977.

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*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, and the National Technical Information Service, Springfield, Virginia 22161.

†Available for purchase from the National Technical Information Service.

APPENDIX C

CALCULATION OF GAMMA RADIATION ATTENUATION FOR RECLAIMED TAILINGS IMPOUNDMENT

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CALCULATION OF GAMMA RADIATION ATTENUATION FOR RECLAIMED TAILINGS IMPOUNDMENT

Assuming soil to be composed mainly of SiO_2, the mass attenuation coefficient for a 1 to 2 MeV gamma ray is 0.0518 cm^2/g.[1] (Most of the dose rate from a typical natural emitter is in this range.[2]) Assuming that the tailings Ra-226 activity of the slimes is 1196 pCi/g, as indicated in Table 2; and the conversion factor[3] of 2.5 uR/hr per pCi/g Ra-226; then the estimated gamma radiation should not exceed 26.2 R/year. If the bulk density of the soil is assumed to be 1.6 g/cm^3, then the effect of the proposed 2.74 m (9 ft) of soil material would reduce the gamma radiation to about 3.60×10^{-9} R/year. The calculation is as follows:

$$I/I_o = \exp[-(\mu_{en}/\rho)\rho x] = \exp[-(0.0518\ cm^2/g)(1.6\ g/cm^3)(274\ cm)] = 1.37 \times 10^{-10};$$

$$I = (1.37 \times 10^{-10})(26.2\ R/year) = 3.60 \times 10^{-9}\ R/year = 3.60 \times 10^{-6}\ mR/year$$

The area's background radiation dose from all sources of radioactivity, including the contribution from fallout, is about 147 mR/year.[4] Thus, the gamma radiation from the deposited tailings after reclamation would be insignificant compared to the natural background radiation.

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APPENDIX D

CALCULATION OF THICKNESS OF REQUIRED COVER MATERIAL

Appendix D

CALCULATION OF THICKNESS OF REQUIRED COVER MATERIAL

D.1 INTRODUCTION

The thickness of cover material required for uranium mill tailings reclamation is usually determined by a radon flux or concentration criterion which must be satisfied. The general approach used in estimating the required thickness of a cover can be divided into two phases. First, the characteristic parameters of the tailings and cover must be measured or estimated. These include the radon diffusion coefficients, porosities and moistures of the tailings and cover, and the radium content and emanating power of the tailings. Second, the thickness of cover needed to achieve a prescribed radon flux is determined by iteratively calculating radon fluxes for various cover thicknesses until the thickness giving the prescribed flux is found. Alternatively, an approximate expression can be used to calculate the cover thickness directly.

In the following equations, the diffusion coefficient for radon in the total pore space of the soil is designated by the symbol D, consistent with recent reports on radon movement. A second parameter, the effective bulk diffusion coefficient of the soil, is often designated D_e, and has sometimes been confused with D due to varying symbols and nomenclature used in the literature. The two are related by $D = D_e/p$, where p is the total soil porosity.

2.1 RADON DIFFUSION EQUATION

The one-dimensional steady-state radon diffusion equation is:

$$D \frac{d^2C}{dx^2} - \lambda C + R\rho\lambda E/p = 0 \quad (1)$$

where

C = radon concentration in the total pore space (pCi cm^{-3})

D = diffusion coefficient for radon in the total pore space ($cm^2 s^{-1}$)

λ = decay constant of radon (2.1×10^{-6} s^{-1})

R = specific activity of radium in the soil (pCi g^{-1})

ρ = dry bulk density of the soil (g cm^{-3})

E = radon emanation coefficient (dimensionless)

p = total porosity of the soil (dimensionless)

The radon flux from the bulk soil material is related to the radon concentration in its pore space by Fick's Law:

$$J = -10^4 \, Dp \frac{dC}{dx}, \quad (2)$$

where

J = bulk radon flux (pCi m^{-2} s^{-1})

10^4 = factor to convert units from pCi $cm^{-2}s^{-1}$ to pCi $m^{-2}s^{-1}$

Verification of Umetco's proposed tailings cover will be performed using the RAECOM computer program since the necessary iterative calculations are best performed by a computer.

The licensee proposed to reclaim the White Mesa tailings impoundments using 9.0 feet of soil and 2 to 4 feet of rock cover to prevent erosion of the soil cover. Estimated input parameters are conservative and no credit was given for radon attenuation by the top layer of rock.

The attached table lists the input parameters utilized for the RAECOM computer program. Results of the RAECOM computer run indicate that approximately 7.5 feet of cover will attenuate radon to 20 pCi/m^2-sec. Therefore, the cover proposed by Umetco for the existing tailings impoundments should attenuate radon to less than 20 pCi/m^2-sec in accordance with the 40 CFR 192 standard. Should the impoundment's size or constituents change from that described in Appendix A of the licensee's renewal application dated May, 1985, a new cover evaluation should be performed.

Table D.1

Parameters Used in URFO RAECOM Run For Umetco White Mesa Mill

	Tailings[1]	Soil
Thickness (cm)	500[2]	274
Porosity[3] (fraction)	0.40	0.39
Diffusion Coefficient (cm^2/s)	0.030	0.012
Radon Source[4] Term ($pCi/cm^3/s$)	0.0012	0
Moisture[4] (%)	8.0	9.0

---

1 Since the licensee will scatter sands and slimes, the tailings are considered to be a homogeneous mixture of sands and slimes.

2 A maximum depth of tailings is assumed.

3 Conservative estimates.

4 From $Q = Rp\,E\lambda/P$ where R = specific activity, p = bulk density, E = emanation fraction, λ = 2.1E-6/s decay constant and P = porosity.

:TCO WHITE MESA MILL

·******* I N P U T P A R A M E T E R S **********

IBER OF LAYERS :	2	
)ON FLUX INTO LAYER 1 :	.000	pCi/m2/SEC
:FACE RADON CONCENTRATION :	.000	pCi/LITER
:ER 2 ADJUSTED TO MEET JCRIT :	20.0	+/- .100E-02 pCi/m2/sec
:E SOURCE FLUX (JO) FROM LAYER 1 :	573.4	pCi/m2/sec

:ER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	SOURCE (pCi/cm3/sec)	MOISTURE (DRY WT. PERCENT)
.	500.	3.0000D-02	.4000	1.2000D-03	8.00
!	274.	1.2000D-02	.3900	.0000D+00	9.00

ıse.
:ase press <return> to continue.

;U L T S O F R A D O N D I F F U S I O N C A L C U L A T I O N

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC
1	500.	2.1185D+02	3.6032D+05	.7602
2	231.	1.9988D+01	.0000D+00	.7187

›p - Program terminated.