FINAL REPORT

DOSE ASSESSMENT FOR UNRESTRICTED FUTURE USE SCENARIOS FOLLOWING LICENSE TERMINATION OF THE HERITAGE MINERALS, INCORPORATED, SITE IN LAKEHURST, NJ.

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December 23, 2005

1. Introduction

On June 7, 2005, Region I (RGN-I) submitted a technical assistance request (TAR) to the Division of Waste Management and Environmental Protection (DWMEP). RGN-I requested that DWMEP perform an assessment of radiological dose to the average member of the critical group, based on realistic future uses of dismantled and remediated mill structures and remediated soil at the Heritage Minerals, Inc. (HMI) site. The TAR further requested that DWMEP determine if the licensed portions of HMI meet the 10 CFR 20 Subpart E dose-based criteria for release for unrestricted use. As described further below, the purpose of the dose assessment is to determine whether, in accordance with approved procedure, the staff must request the Commission's approval to terminate HMI's license (License SMB-1541).

HMI is not required to meet the 10 CFR 20 Subpart E radiological criteria for license termination. HMI's decommissioning plan was approved prior to August 20, 1999. For this reason, and in accordance with Commission policy, HMI must meet the decommissioning criteria specified in Option 1 of the 1981 Branch Technical Position on "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" (46 FR 52061) and U.S. Nuclear Regulatory Commission (NRC) Policy and Guidance Directive FC 83-23, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use for Termination of Byproduct, Source, and Special Nuclear Material Licensees." The purpose of the staff's dose assessment is solely to determine whether staff may terminate HMI's license, after HMI meets the applicable criteria, without prior approval from the Commission.

DWMEP staff conducted a comprehensive review and assessment using HMI site characterization and survey data. On July 19, 2005, DWMEP and RGN-I staff visited HMI to become familiar with site physical conditions and environmental surroundings. Subsequently, the staff evaluated potential future use scenarios of the HMI site. Based on these analyses and evaluations, suburban resident and resident farmer unrestricted release exposure scenarios were selected as future land uses. The re-use of the former building foundations (mill pads) was evaluated using a probabilistic approach using RESRAD-BUILD v. 3.22. For the soil areas, a probabilistic dose analysis using site specific parameters and applicable scenarios was performed using RESRAD 6.3.

2. Background

2.1 Site Location and Description:

The HMI facility is located in Lakehurst, Manchester Township, Ocean County, New Jersey. It is approximately 50 kilometers (30 miles) southeast of downtown Trenton, New Jersey. The site is bounded on the north and west by Route 70, on the northeast by the Central Railroad tracks and privately-owned properties, and on the south by the State of New Jersey and corporate or privately-owned properties. The overall site area is located on the Atlantic Coastal Plain. The area is characterized by sandy deposits that resulted from processes involving surface erosion, transport of eroded materials via slowing streams or water bodies, and deposition by wind creep and saltation in a shallow surface water environment. The deposition processes continued for sometime, accumulating thick deposits reaching a depth of 500 m (1500 feet). The bedrock is not encountered until a depth of 1000 m (3000 feet). The sandy deposits are typically permeable. The upper most shallow aquifer (the Cohansey aquifer) at the site is reached at a minimum depth of approximately 2 m (6 feet). However, the average depth of shallow wells at the site for industrial water use could reach approximately 8 m (25 feet). The plant manager indicated that the shallow aquifer well water may not be appropriate for drinking without a proper treatment to remove the high content of iron. However, the deep aquifer water at a depth of few hundred feet could be more appropriate for drinking.

The area is covered by vegetation, shrubs, and trees. There are some farms located within approximately 3 to 5 km (2-3 miles) of the site. The area also adjoins some creeks, streams, small lakes, and marshy land.

The entire site has an area of 2,800 hectares (7,000 acres) with approximately 116 hectares (287 acres) involved in the mining operations prior to licensing. The NRC licensed area comprises about 0.4 hectares (1 acre) across three non-contiguous areas on the site: two concrete pads, which are what remains of the Wet Mill and the Dry Mill; and the footprint of a large pile of monazite-rich sand that has been removed.

2.2 Historical Site Assessment

ASARCO Operations (1973-1986)

From 1973 to 1982, HMI's predecessor company, ASARCO, conducted mining of the sand deposits (e.g., dredging), hydraulic (wet) gravity processing, and electro-magnetic (dry) separation to extract heavy minerals, such as, ilmenite from the sand. ASARCO mining and wet processing involved creating a pond for the dredge, pumping the dredge sand to a screening barge at a rate of about 1090 metric tons (MT) (1,200 tons) per hour, and then pumping the sand in a slurry to a processing plant where heavy minerals were concentrated using numerous spiral separators. This integrated wet gravity process was conducted in the 'Wet Mill.'

The wet mill tailings (mostly silica sand and water) are normally returned to the moving dredge pond as backfill. However, to enlarge the original dredge pond for adequate space for the dredging and operating equipment, the original one million tons of tailings (referred to as the ASARCO wet mill tailings) were stored at the dredge construction site located to the west of the old Central Railroad tracks.

Based on its history, the radionuclide concentration of these mine tailings is below the natural background concentration of the area and, hence, not licensable source material since all the heavy mineral fraction that contained monazite has been removed.

The heavy mineral fraction followed a different path downward through the spirals, and was dewatered, and stockpiled, outside the Wet Mill, for further processing at the rate of 45 metric tons (50 tons) per hour.

The excess wash water, containing the suspended clay washed from the heavy mineral fraction, was processed by decanting using the Wet Mill holding tanks (sumps). It was, then, pumped to a series of large area settling ponds located to the north of the Wet Mill. These settling ponds are identified as the 'Blue Area.'

The stockpiled heavy fraction contained monazite (Fe, Ce, U, Th, PO_4 , and $ZrSiO_4$), the concentration of which had been increased by a factor of 24. The factor of 24 is calculated by dividing the 1090 MT (1,200 tons) of dredged sand per hour by the 45 MT (50 tons) of heavy fraction produced per hour. The drained heavy mineral concentrate was transferred into a storage silo, and then fed by a conveyor into an oil-fired rotary kiln for drying at 167.5 °C (300 °F). The dried heavy sand fraction was then transferred to the Dry Mill for high-tension electrostatic separation and high-intensity magnetic separation.

The Dry Mill electrostatic process removed the electrically conductive mineral ilmenite for commercial use at a rate of about 27 MT (30 tons) per hour. Other minerals remaining in the concentrate were non-conductors and referred to as the Dry Mill tailings, which were produced at a rate of about 18 MT (20 tons) per hour. The Dry Mill tailings were mixed with water and pumped to a storage area east of the mill, which is also referred to as the 'Gray Area.'

NRC conducted an inspection of the Gray Area in January 1988 and collected soil samples. The Dry Mill tailings were determined by NRC to contain 180 parts per million (ppm) thorium plus uranium (Th+U). Therefore, the one million tons of material accumulated in the Gray Area contains less than 0.05 wt% (i.e., 500 ppm) uranium and thorium, and is not licensable source material.

ASARCO discontinued all operations at the site in 1982. In April 1982, ASARCO leased the site to Humphrey's Gold, Inc. for pilot scale tests of zircon extraction from the Dry Mill tailings. Humphrey's Gold operated the Wet Mill and Dry Mill for one month and placed test products and tails in the Gray Area. ASARCO sold the property to HMI in 1986.

HMI Operations (1986-1990)

From October 1986 through August 1987, Mineral Recovery, Inc. (MRI) refurbished parts of the Dry Mill and conducted minimal break-in and tune-up operations at the site under a lease from HMI. HMI terminated MRI's lease in 1987 and started full-scale operations to recover zircon and additional titanium-bearing minerals that were left in the Dry Mill tailings located in the Gray Area. These Phase I operations continued (as described below) until February 1990, when the Gray Area feed was exhausted.

Phase I (1987-1989)

In the secondary process, the ASARCO Dry Mill tailings stockpiled in the Gray Area were mixed with water to form a slurry that was pumped to the Wet Mill at a rate of about 45 MT (50 tons) per hour. The vacuum-dried, heated product from the Wet Mill was fed to the Dry Mill titanium circuit. The wet mill tails were pumped to the area north of the wet mill now referred to as the Blue Area.

The product of the Dry Mill titanium circuit was market-grade leucozene, a titanium-bearing mineral. The Dry Mill titanium circuit tailings were recycled to the Wet Mill by slurry with water. An NRC sample of the Dry Mill titanium circuit product showed that it contained 140 ppm Th+U, or less than the 500 ppm licensable limit.

Back at the Wet Mill, the recycled Dry Mill titanium circuit tailings were further refined by a hydraulic classifier and shaking tables. The second Wet Mill product stream was sent to another section of the Dry Mill called the 'zircon circuit.' The product of the zircon circuit was market-grade zircon containing 350 ppm Th+U. The zircon circuit tails, containing zircon and monazite, were fed to high-intensity magnets, which removed monazite, staurolite, and tourmaline. The product of the high-intensity magnets was market-grade zircon containing 350 ppm Th+U.

The tails of the magnetic separation stage, containing monazite, was slurried and returned to the Wet Mill, combined with other tailings and ultimately returned to the Blue Area. These tailings contained 120 ppm Th+U, as determined by NRC inspectors, and therefore, contains less than 0.05 wt% (i.e., 500 ppm) uranium and thorium, and is not licensable source material.

During Dry Mill operations, both ASARCO and HMI used "Mill Shutdown Avoidance Procedures" when equipment malfunctioned. This cost-savings procedure allowed the operable equipment in the mill to continue operating while any inoperable unit was being repaired or replaced. This practice resulted in heavy mineral concentrates being conveyed through portals in the south wall and stockpiled on the ground. Depending on which equipment failed, the dumped material could have contained monazite in concentrations exceeding 0.05 wt% Th+U. These spills were routinely graded and re-graded onto the surface and into the subsurface.

Phase II (1990)

In early 1990, HMI had decided that sufficient zircon and titanium remained in the Blue Area tailings to warrant a second round of processing known as the Phase II of HMI operation. In this phase, tailings (enriched in monazite) of the Phase II operations were stored in a controlled area southeast of the Dry Mill known as the “Monazite Pile.” In August 1990, after the processing of about 181,500 MT (200,000 tons) of tailings, HMI decided to terminate all operations due to economic turndown. The processing of the 181,500 MT (200,000 tons) of plant tailings resulted in the production of about 1270 MT (1,400 tons) of monazite rich product generated and stored in the Monazite Pile area.

HMI submitted an application for an NRC license on March 10, 1989. When the license was issued in January 1991, HMI had terminated all mineral recovery operations. The current license does not authorize production of source material, but directs the licensee to decontaminate buildings, equipment and the soil area at the monazite pile in accordance with NRC’s Office of Nuclear Material Safety & Safeguards (NMSS) Policy and Guidance Directive FC 83-23, “Termination of Byproduct, Source and Special Nuclear Material Licenses,” and Option 1 of the Branch Technical Position “Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations,” 46 FR 52061 (October 23, 1981) before areas are released to unrestricted use.

As a result of operations at ASARCO and HMI described above, the areas of the site affected by the handling and use of licensable source material were the Monazite Pile area, the Wet Mill and the Dry Mill.

2.3 Cleanup, Survey, and Decommissioning Activities:

After the plant shut down in August, 1990, both mills (e.g., Wet and Dry Mills) were cleaned commercially. Equipment in the Wet Mill, used in Phase II operation, was washed down with high-pressure water until no sand was visible on or around the equipment. The sand and water remaining in the sumps and pumps were drained, collected, and transported to the “Monazite Pile.” The equipment and structures in the Dry Mill were cleaned using high pressure air hoses.

After the plant cleanup, a gamma survey was performed in early 1991 on the buildings and equipment. In 1996, a survey of the natural background levels of U and Th within the soils was conducted by Radiation Science, Inc. In March 1997 and July 1997, Camp Dresser & McKee, Inc. conducted an investigation to characterize the mine tailings at the HMI site. The investigation consisted of surface gamma radiation survey, a subsurface soil investigation, and a groundwater and surface water investigation. The groundwater and surface water investigation confirmed that no significant radionuclide transport or elevated concentrations are occurring in the surface water or the aquifer system at the site.

In November 1997, HMI submitted a Final Status Survey Plan (FSSP) and requested unrestricted site release. HMI started remediation activities in 2001, after NRC's approval of the FSSP in 1999. In 2001, the material in the Monazite Pile was packaged in Department of Transportation approved inter-modal containers and shipped via truck and rail to International Uranium Corporation in Blanding, Utah, for use as an alternate feed material for the uranium mill. The packaging at the site was accomplished using a front-end loader to transfer material to waste packages. During loading, dust control measures were applied using mainly a water spray system in the area surrounding the pile. Residual monazite sands in the surface and subsurface soils were also removed.

HMI submitted a Final Status Survey Report (FSSR) in November 2001. An NRC confirmatory survey in December 2001 (report dated March 2002) identified several areas where licensable material was still present. NRC subsequently informed HMI that additional decommissioning actions would be necessary.

In May 2003, NRC approved a revised decommissioning plan which included demolition of the mill structures and the removal of pockets of fugitive licensable material in the soil. The demolition of the mill structures resulted in the creation of a stockpile of licensable material south of the Dry Mill, near the former monazite pile. This stockpile contained contaminated sand with total Th concentrations of 25-27 pCi/g, which is less than the 116 pCi/g value that corresponds to 0.05 wt% total Th (^{228}Th + ^{232}Th).

In April 2003, Enercon, HMI's decommissioning contractor, implemented an approved decommissioning strategy.

In December 2003, another NRC confirmatory survey revealed the presence of nine additional pockets of fugitive licensable material in soils north of the Wet Mill pad, near the Dry Mill pad, and in and around the footprint of the former monazite pile. In June 2004, HMI provided NRC with a proposal to complete decontamination and disposal of remaining fugitive licensable soils within an identified buffer zone surrounding NRC-licensed areas. This proposal included disposition of the stockpiled waste soil that was created during dismantling and decontamination of the mill structures in 2003.

In November 2004, NRC approved HMI's proposal to remediate any material within the buffer zone which exceeds the unimportant quantity limit (116 pCi/g of total Th). NRC also directed HMI to dispose of the stockpiled waste as licensed material.

In December 2004, NRC inspectors observed excavation and shipping activities at HMI. Thirteen split samples were obtained with Enercon personnel from the nine excavated soil locations (ORISE 1-9). The stockpiled waste had not been completely removed, and would be sampled during a subsequent inspection. Enercon detemined that four locations sampled in December required additional excavation to meet the release criteria. These locations were re-sampled in January 2005, along with the area under the former stockpiled waste.

3. Objective

The first objective of this study is to evaluate and select the appropriate scenarios compatible with the unrestricted use of HMI facilities (e.g., mill pads as well as soils contaminated with residual radioactivity). The second objective is to assess the dose impact to the average member of the critical group, as defined by the scenarios, from exposures to indoor and outdoor areas containing residual radioactivity. The purpose of the dose assessment is to determine whether the staff must request the Commission's approval to terminate HMI's license (SMB-1541).

4. Analysis Methodology

Staff evaluated available information on the HMI site and its surroundings. The information included the general geology, the hydrology, the demography, and the generic activities of inhabitants within a few mile radius from the site. Such information helped the staff in assessing the potential uses of mill pads, as well as the selection of appropriate scenarios based on site-specific conditions and possible uses of HMI facilities. The staff evaluated the available site-specific characterization and survey data to assess the extent of contamination (e.g., horizontal/ vertical) and subsequently establish the appropriate source term(s) for the dose modeling analysis. The staff also evaluated surface water and groundwater monitoring data, as well as survey information on radiological background levels and the unaffected areas.

The main radionuclides of concern in this analysis include: total uranium (primarily, ^{238}U + ^{234}U) and total thorium (^{232}Th + ^{228}Th) in equilibrium with progeny in their respective decay chains.

For the mill pads, staff evaluated final status survey data contained in the March 2005 license termination request. This data include gross beta readings of removable and fixed plus removable contamination that remains on the pads. Gross readings using the Ludlum 43-68 alpha/beta detector were converted to estimates of area concentrations (pCi/m^2) of ^{232}Th and its progeny, assuming secular equilibrium. Thorium-232 was selected, rather than ^{238}U, or any combination of the two, because ^{232}Th results in a higher dose (mrem/yr) per unit of surface activity (pCi/m^2). A statistical summary of pad contamination level measurements is provided in Table 1.

To estimate the average uranium and thorium concentrations within the monazite pile footprint, staff used the final confirmatory survey results for soil samples obtained by Enercon in April 2003, and confirmatory sample results obtained by NRC in 2003 and 2004. These sample results are provided in Table 2. To calculate the isotopic concentrations, total uranium is assumed to be natural uranium with 49% of the activity being U-238, 49% U-234, and 2% U-235. Therefore, the average isotopic concentrations are 2.37 pCi/g of U-238 and U-234 each, and 0.1 pCi/g of U-235. For total thorium, the activity is 50% from Thorium-228 and 50% from Thorium-232, and therefore, the isotopic concentration is 2.3 pCi/g each.

Table 1. Statistical Summary of Wet and Dry Pad Residual Surface Contamination Levels (1)

Statistic	**Total DPM/100 cm^2**	**^{232}Th, Bq/m^2** (2)
Minimum Value	0	0
Maximum Value	442	74
Average Value	180	30

Notes:
(1) Statistics based on 60 measurements of the Wet Mill and Dry Mill pads.
(2) Estimate of ^{232}Th surface concentration is based on an assumption that 10% of measured alpha/beta radiation measured using a Ludlum 43-68 is ^{232}Th, with remainder attributable to ^{232}Th daughters in secular equilibrium. The factor for converting from DPM/100 cm^2 to Bq/m^2 is 1.67.

Table 2. Soil Sample Results Inside the Monazite Pile Footprint: Background Subtracted

Sample ID	Date	Total Uranium, pCi/g	Total Thorium, pCi/g
NRC-04-07	December 2004	3.15	11.78
NRC-04-08	December 2004	1.75	5.12
ORISE 36	September 2003	<background	0.38
ORISE 37	September 2003	0.65	1.5
ORISE 38	September 2003	4.65	10.06
17-10	April 2003	7.5	5.57
17-10N	April 2003	4.38	1.64
17-10E	April 2003	5.35	10.55
17-10S	April 2003	3.1	0.4
17-10W	April 2003	9.55	3.24
17-11	April 2003	3.25	1.73
17-11N	April 2003	7.28	4.1
17-11E	April 2003	5.58	3.6
17-11S	April 2003	9.62	5.38
17-11W	April 2003	6.75	4.07
	Average	4.84	4.6

5. Data Analysis and Exposure Scenarios

5.1 Scenario for Soil Unrestricted Use

The staff employed the approach in NUREG-1727 for analysis of potential exposure pathways from unrestricted use of decommissioned soil. The staff evaluated the physical conditions at the site (e.g., soil characteristics, groundwater conditions, climate, topography, and geology) and current inhabitants' activities around the site.

Year 2000 census information indicates that in Manchester Township, NJ, only about 0.1% of the population works in the farming, fishing, or forestry occupation. Also, the NJ Department of Labor and Development projects that there will be no job growth in these occupations in Manchester Township through 2012. Further, a distinct majority of the population in Manchester Township (64.7%) is over 55 years old, with a median age of 67.7 years. There are currently 217 small farms covering about 12,239 acres in Ocean County, which is less than 3% of the county's land area of 636 sq. miles. The property owner is specifically interested in building residences at the site.

The soil in Ocean County is sandy with some silt and clay contents and is suitable for agricultural uses. Therefore, there is no physical evidence to exclude the potential use of the soil in farming activities. The quality (e.g., salinity) and quantity of well water (withdrawn from shallow and deep aquifers) is appropriate for irrigation, livestock, and human domestic uses. Though a plant manager had previously indicated that the shallow groundwater was unsuitable for drinking due to high iron concentrations, staff have conservatively assumed that the water is potable, as described below.

Given the land use patterns and demography of Manchester Township, and the interest of the current owner in developing the site for residential use, staff postulated that a suburban resident is a reasonably foreseeable future use scenario for unrestricted use of the HMI site. A suburban resident would be subjected to several radiological pathways, including direct radiation exposure; inhalation and ingestion of re-suspended soil; and ingestion of produce grown in a private garden. It is unlikely that a suburban resident would either be exposed to groundwater from a private well, or could raise animals using feed and water from potentially contaminated sources. A suburban resident is also unlikely to obtain fish from a pond filled with water from a potentially contaminated aquifer.

Staff also evaluated a resident farmer scenario. Though this scenario is considered less likely than that of the suburban resident, it is evaluated here for completeness. A resident farmer would be exposed to the same pathways as the suburban resident, and the following additional pathways: Use of a contaminated aquifer to supply irrigation; ingestion of animal products grown onsite and using feed and water from potentially contaminated sources; ingestion of fish from a pond filled with water from the aquifer; and human ingestion of drinking water from the aquifer.

5.2 Mill Pad Scenario

This portion of the site is comprised of two pads remaining from dismantlement of the Wet Mill (WM) and Dry Mill (DM) buildings. The WM pad is 69.8 m (229 ft) long x 30.2 m (99 ft) wide, which is an area of 2108 m^2 (22,671 ft^2). The DM pad is approximately 36.6 m (120 ft) long x 29.0 m (95 ft) wide, which is an area of 1061 m^2 (11,400 ft^2). A plausible exposure scenario involves both direct radiation exposure to residual monazite present on the pads, and inhalation of monazite dusts by an individual on or near the pads. The pads are either in too poor condition following dismantlement, or are too specialized in design (including monolithic concrete forms and structures used to bear extremely heavy processing equipment), to be useful as foundations for future structures.

6. Assumptions and Input Parameters

For contamination on pads, the following assumptions and parameters were used:

<u>Pad Assumptions:</u>

(i) The receptor is assumed to be in the center of the pad. Pad centers were determined by the specific building dimensions (e.g., WM: 69.8 m x 30.2 m; and DM: 36.6 m x 29 m).

(ii) The occupancy factor is estimated to be 0.75. No shielding factor is applied.

(iii) The dose is estimated using RESRAD-BUILD v. 3.22.

(iv) The surface concentration of Thorium-232 is calculated for the average value of fixed plus removable contamination remaining on the pad (see Table 1).

Table 3 presents important input parameter values used in RESRAD-BUILD v. 3.22. Table 3 also presents sensitive parameters and corresponding distributions selected for RESRAD-BUILD probabilistic runs.

For contamination in the surface soil the following assumptions and parameters were used:

<u>Surface Soil Assumptions:</u>

(i) The contamination is homogeneously distributed in the top 1.0 m.

(ii) There is no surface soil cover layer (e.g., thickness of cover was set to zero).

(iii) An average annual precipitation of 1.20 m was selected.

(iv) The thickness of the unsaturated layer was assumed to have a bounded log-normal distribution with a mean value of 2.00 m, a standard deviation of 1.276 m, a minimum thickness of 0.18 m, and a maximum thickness of 10.0 m.

(v) The area of contaminated zone was assumed to be 2000 m^2.

(vi) The length parallel to the aquifer was assumed to have a uniform distribution with a minimum value of 20 m and a maximum value of 200 m.

(vii) The distribution coefficients for each isotope of uranium and thorium for the contaminated zone, the unsaturated zone, and the saturated zone were assumed to have log-normal distribution. All the isotopic distributions were assumed to be perfectly correlated with each other (i.e., the distribution coefficient for U-234 was highly similar to the distribution coefficient for U-238).

(viii) The consumption rates of food-stuffs and both indoor and outdoor exposure times is based on the critical group descriptions in NUREG/CR-5512, Volume 3.

(ix) The contamination fraction for the resident farmer is calculated by RESRAD using an area factor. For the suburban resident, the contamination fraction is set to 0.1.

(x) The soil-to-plant transfer factors were assumed to have a log-normal distribution for each radionuclide.

(xi) The soil was assumed to be primarily of a sandy silt soil. Therefore, soil physical parameters were selected to correspond with the assumed soil type.

(xii) Groundwater was assumed to be uncontaminated (e.g., with background concentration). The critical group receptor drinking water intake was assumed to be 510 L/yr for the resident farmer scenario. The suburban resident is not assumed to use a well onsite.

(xiii) The depth of roots for the plants used the default uniform distribution from RESRAD with a minimum value of 0.3 m and a maximum value of 4 m.

<u>Surface Soil Input Parameters Selections:</u>

Table 4 presents important input parameters values used in RESRAD 6.3. Table 5 presents sensitive parameters and corresponding distributions selected for RESRAD 6.3 probabilistic runs.

7. Results

The dose to a potential suburban resident and resident farmer was calculated for the pads and surface soil. The approach and methodology are described above. The assumptions and input parameters and distributions used in this dose assessment are listed in Tables 1-5. Table 6 presents a summary of the doses derived for pads and soil within the former monazite pile footprint.

The Total Effective Dose Equivalent (TEDE) to an individual standing on or near either pad is about 1.6 mrem in the first year. The dose decreases significantly in the second year and thereafter, because the removable component of the source is nearly all blown downwind during the first year. The important pathways for the first year dose on the pad include ingestion (94% of the TEDE), and inhalation (6% of the TEDE). The dose during the second year is 0.0065 mrem/yr, which is all attributable to the direct radiation (external) dose pathway.

The peak of the mean TEDE to a suburban resident living within the footprint of the former monazite pile is about 40 mrem/yr, which occurs in the first year following termination. The direct radiation dose pathway is predominant, with the predominate radionuclides being radium-226, thorium-228, and thorium-232. The dose to the resident farmer is higher, with the peak of the mean TEDE of about 83 mrem/yr. For the resident farmer, the direct radiation dose and water-independent produce consumption pathways, for radium-226, thorium-228, and thorium-232, are predominant. For the farmer, soil ingestion contributes about 1% of the TEDE, and meat and milk ingestion, and dust inhalation pathways combined contributing another 1%.

Table 3. RESRAD-BUILD Important Input Parameters for Mill Pads

Parameter	Unit	Value	Distribution	Remarks
^{232}Th Concentration	Bq/m^2	30	NA	Table 1
Receptor location	m	22.9, 22.9, 1.5	NA	1.5 m height from source
Receptor exposure duration	d	365.25	NA	
Indoor fraction		0.75	NA	
Receptor time fraction		1		receptor is located in one room
Deposition velocity	m/s	0	NA	assumes windborne dust does not settle
Resuspension rate	1/s	5E-7	Log-Uniform min 2.8E-10 max 1.4E-05	default
Room height	m	3	NA	
Air exchange rate	1/h	78.5	Uniform min 40 max 200	air exchange caused by wind on an open pad
Receptor inhalation rate	m^3/d	28.8	NA	light industry
Number of sources		1	NA	one room
Source direction		floor Z	NA	perpendicular to the exposed area
Air release fraction		0.1	triangular mode 0.07 lower quantile 1E-05 upper quantile 0.75	
Room area	m^2	2108	NA	Wet mill pad area
Direct ingestion rate	1/h	4.91E-7	loguniform min 1.0E-7 max 1.0E-6	
Removable fraction		0.2	NA	based on pad survey results
Time for source removal	d	365	NA	
Shielding thickness	cm	0	NA	

Table 4. **RESRAD 6.3 Important Input Parameters for Surface Soil**

Parameter	Unit	Value	Distribu-tion	Remarks
Radionuclide Concentration, ^{234}U	pCi/g	2.37	NA	Average values calculated from data in Table 2
Radionuclide Concentration, ^{235}U	pCi/g	0.1	NA	
Radionuclide Concentration, ^{238}U	pCi/g	2.37	NA	
Radionuclide Concentration, ^{228}Th	pCi/g	2.3	NA	
Radionuclide Concentration, ^{232}Th	pCi/g	2.3	NA	
Cover depth	m	0.0	NA	
Thickness of contaminated zone (CZ)	m	1.0	NA	Based on survey results
Density of contaminated zone (CZ)	g/cm^3	1.50	NA	Soil type & licensee value
Area of CZ	m^2	2000	NA	
Length parallel to aquifer flow	m	20-200	Uniform	
CZ erosion rate	m/yr	1.0E-03	NA	RESRAD Default
CZ & unsaturated zone (UZ) hydraulic conductivity	m/yr	20	NA	Site
Precipitation Rate	m/yr	1.20	NA	Site
UZ thickness	m	0.15	NA	Site
Saturated zone (SZ) hydraulic conductivity	m/yr	200	NA	Site
Contamination Fraction (suburban resident)	-	0.1	NA	RESRAD Default
Indoor Time Fraction	yr	0.657	NA	NUREG/CR-5512, Vol. 3
Outdoor Time Fraction	yr	0.11	NA	NUREG/CR-5512, Vol. 3
Fruit, Vegetable, Grain Consumption	kg	112	NA	NUREG/CR-5512, Vol. 3
Leafy Vegetables Consumption	kg	21	NA	NUREG/CR-5512, Vol. 3

Table 5. Sensitive Parameters and Corresponding Distributions Selected for Resrad 6.3 Probabilistic Runs for Surface/subsurface Contamination

Parameter/Unit	Distributions	Mean (Mu), Standard Deviation & Other Parameters
K_d for Uranium isotopes (CON, US, and SAT zones); cm^3/g (correlated)	Log-Normal	Mu 1.75 σ 3.15
Plant transfer factor for Uranium; dimension less	Log-Normal	Mu -6.21 σ 0.916291
K_d for Thorium (CON, US, and SAT zones); cm^3/g (correlated)	Log-Normal	Mu 6.1 σ 1.7
Plant transfer factor for Thorium; dimension less	Log-Normal	Mu -6.91 σ 0.916291
K_d for Radium isotopes (CON, US, and SAT zones); cm^3/g (correlated)	Log-Normal	Mu 8.17 σ 1.7
Plant transfer factor for Radium; dimension less	Log-Normal	Mu -3.22 σ 0.916921
Length parallel to aquifer, m	Uniform	Min 20 Max 200
Unsaturated zone thickness, m	Bounded Log-Normal	Mu 2.0 σ 1.276 Min 0.18 Max 10.00
Depth of Roots, m	Uniform	Min 0.3 Max 4

Table 6. Total Effective Dose Equivalent for Potential Future Land Uses at Heritage Minerals, Inc, Lakehurst, NJ

<table>
<tr><th>Survey Units</th><th>Source Description</th><th>Radionuclides</th><th>Average TEDE, mrem/year</th></tr>
<tr><td rowspan="3">Wet Mill
and
Dry Mill Pads</td><td rowspan="3">Concrete pads remaining from dismantled buildings and structures</td><td rowspan="6">(Monazite)

U-238 +
U-235 +
U-234 +
Th-232 +
Th-228 +
progeny in secular equilibrium</td><td rowspan="3">1.6</td></tr>
<tr></tr>
<tr></tr>
<tr><td rowspan="3">Former monazite pile footprint</td><td rowspan="3">Outdoor sandy soil contaminated with residual radioactivity</td><td>Peak of the Mean TEDE, mrem/year</td></tr>
<tr><td>(suburban resident)
40

(resident farmer)
83</td></tr>
<tr></tr>
</table>

8. Summary and Conclusion

Staff evaluated scenarios for reuse of HMI pads and the outdoor surface soil at the site of the former monazite storage pile. Staff calculated the dose to the average member of the critical group for each scenario. These doses were calculated using a probabilistic methodology based on the RESRAD-BUILD v. 3.22 model for the pad scenario, and probabilistic RESRAD 6.3 codes and specific input parameters or parameter distributions for the monazite pile footprint which correspond to HMI site-specific conditions.

The dose result for the average member of the critical group exposed to residual radioactivity at the monazite pile footprint means that the staff requires Commission approval to terminate the HMI license (License SMB-1541).