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Div of Waste Management
and Radiation Control

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SENT VIA E-MAIL AND EXPEDITED DELIVERY

Mr. Ty L. Howard
Director
Division of Waste Management and Radiation Control
Utah Department of Environmental Quality
195 North 1950 West
Salt Lake City, UT 84116

Re: Response to Utah Division of Waste Management and Radiation Control ("**DWMRC**") Request for Additional Information (RAI) regarding the Energy Fuels Resources (USA) Inc. ("**EFRI**"), June 25, 2020 Letter Regarding Receipt and Processing of Ores from Chemours at the White Mesa Uranium Mill Utah (the "**Mill**"); Groundwater Discharge Permit No. UGW370004 ("**GWDP**") and Utah Radioactive Materials License UT 1900479 ("**License**")

Dear Mr. Howard:

This letter responds to DWMRC's letter dated July 21, 2020 regarding the DWMRC Request for Additional Information ("**RAI**") regarding EFRI's, June 25, 2020 letter regarding receipt and processing of ores from Chemours at the Mill (the "**Ore**") for the recovery of uranium and a rare earth element ("**REE**") concentrate ("**REE Concentrate**").

As will be discussed in detail below in response to DWMRC's questions, the Ore is a natural uranium ore that is similar in radionuclide and chemical content to other ores and alternate feed materials that are processed on a routine basis at the Mill. The Ore can be processed at the Mill for the recovery of uranium and an REE Concentrate under existing processes and standard operating procedures with minor routine modifications and adjustments typical of the types of modifications and adjustments made by the Mill in its normal processing activities associated with the various ores and feeds it processes on a regular basis.

Because all the constituents in the Ore have either been reported to be, or can be assumed to be, already present in the Mill's Tailings Management System ("**TMS**") or were reported in other conventional ores or licensed alternate feed materials, or in reagents already in use at the Mill, at levels generally comparable to or higher than those reported in the Ore, the resulting tailings will not be significantly different from existing tailings at the facility, and the impacts will not be significantly different from the Ore than from other conventional ores and previously licensed alternate feed materials. Consequently, there will be no incremental public health, safety or environmental impacts over and above existing licensed activities.

As a result, although not expressly evaluated in previous analyses, the process of extracting an REE Concentrate has been environmentally evaluated for the Mill, through the evaluation of similar activities.

Although this letter responds to DWMRC's questions relating to the Ore, the analysis below demonstrates that natural monazite sand ores having similar characteristics as the Ore can be handled easily and safely at the Mill in much larger volumes than the volumes associated with the Ore as set out in our June 25, 2020 letter. Our June 25, 2020 letter contemplated receipt of approximately 5,000 tons of Ore from Chemours' mines per year over a ten-year period. For purposes of the analysis below, however, we have assumed annual receipts of 15,000 tons of Ore or similar natural monazite sand ores per year from other sites on an ongoing basis, in order to analyze any potential impacts if the Mill were to receive additional monazite sands with similar characteristics from other sites in the future. As will be evident from the following analyses, the receipt, processing and disposal of the tailings from 15,000 tons of natural monazite sands similar to the Ore per year on an ongoing basis would fall well within the environmental envelop for the Mill and would result in no incremental public health, safety or environmental impacts over and above previously licensed activities. In fact, as demonstrated in this letter, even quantities of Ore or similar natural monazite sand ores double that amount (i.e., 30,000 tons per year on an ongoing basis) could be handled easily and safely at the Mill with no incremental public health, safety or environmental impacts over and above previously licensed activities.

For ease of review, the DWMRC comment or request has been repeated in italics, below, followed by EFRI's response.

DWMRC COMMENT

RAI 1 – Additional information needed to support claims of 0.26% U_3O_8 in the Chemours Monazite Mineral Sand meet the definition of uranium ore

EFRI states on page 4 of the letter that the Chemours material has a grade of 0.26% U_3O_8. The EFRI letter includes an Attachment D Table which is referred to as "a summary of the mineral composition of a typical ore produced in 2019" (Page 4). It is assumed that the EFR letter is claiming that the Chemours monazite sand will contain a consistent percentage of recoverable uranium, however, there is no source for the data provided in Attachment D and no way to confirm that consistent percentages will be present for all material accepted at the Mill. Please provide the data and sources used to claim the U_3O_8 concentrations of the Chemours Material as well as justification that all material received from the Mission mine and the multiple future mines and sources of mineral sand will contain a consistent percentage of recoverable uranium.

At a minimum, it needs to be documented with analytical data that the Chemours material will always meet the definition of source material ore per the Utah Administrative Code R-313-12-3 (see also 10CFR40.4) contain by weight one-twentieth of one percent (0.05 percent) of uranium for acceptance at the White Mesa Uranium Mill.

EFRI RESPONSE:

The data in Attachment D of the June 25, 2020 letter was provided by Chemours on December 25, 2019. In July 2020, Chemours provided additional mineral and uranium data for the Ore separated at the Offerman site from a range of sand sources at the Mission Mine. The uranium data is provided in Table 1, attached to this response letter. Table 1 includes the U_3O_8 and U-nat value from EFRI's June 25, 2020 letter to DWMRC, which was provided to EFRI by Chemours as what Chemours believed would be representative of "typical Ore" to be sent to the Mill (referred to in Table 1 as "Sample data from email"), as well as data from other samples collected by Chemours during 2019-2020 (referred to in Table 1 as Rem(s) 1-6). The data show a range of 0.18% to 0.26% U_3O_8, with an average of 0.20% U_3O_8 (0.15% U-nat to 0.22% U-nat, with an average of 0.17% U-nat). All samples contained greater than 0.18% U_3O_8 (0.15% U-nat).

We have also provided in Table 1 the typical, minimum, and maximum uranium content data from other separated monazite sands, produced in Africa, and identified at Queensland, Australia (WNA 2019). These are expected to be typical of other monazite sand ore sources that EFRI may evaluate for processing in the future. All samples from every source (not just the average of samples) contained 0.1% or higher U-nat grades.

Based on the above information, the Ore, and other typical natural monazite ores that may be considered by EFRI in the future, are expected to meet the definition of source material ore.

Having said this, however, ores received at the Mill do not need to have a concentration of 0.05% U-nat or higher.

When reviewing a prior U.S. Nuclear Regulatory Commission ("**NRC**") interpretation of the Atomic Energy Act's ("**AEA's**") definition of byproduct material, the Court of Appeals for the District of Columbia Circuit found that under the Uranium Mill Tailings Radiation Control Act ("**UMTRCA**") "low-grade feedstock ore containing less than the 0.05% uranium necessary to constitute source material" could be treated as "ore" for the purpose of the definition of 11e.(2) byproduct material (which means that processing any such ore primarily for the recovery of uranium would result in 11e.(2) byproduct material, and would be acceptable). See *Kerr-McGee Chemical Corp. v. NRC*, 903 F. 2d 1 (D.C. Cir. 1990).

In that case, the Court stated:

> Throughout the AEA, different classes of materials are dealt with in accordance with their physical properties and place within the nuclear fuel cycle. The UMTRCA is no different. In section 11(e) (2), as originally presented in the UMTRCA, byproduct material was defined as "the tailings or wastes produced by the extraction or concentration of uranium or thorium from source material." H.R. 13382, 95th Cong., 2d Sess. Sec. 1 (1978) (emphasis added). Because of his concern that tailings resulting from the processing of low-grade feedstock ore containing less than the 0.05% uranium necessary to constitute source material

> under NRC rules would escape regulation under the proposed definition, then-NRC Chairman Dr. Hendrie suggested that the definition of byproduct materials proposed in section 11(e) (2) be revised to substitute "any ore processed primarily for its source material content" (the language now appearing in the section) for the words "source material." Hearings at 343. When questioned as to the significance of the phrase "processed primarily for its source material content," Dr. Hendrie explained that the language was intended to avoid bringing within NRC jurisdiction radioactive wastes resulting from activities not connected with the nuclear fuel cycle, which would be left to EPA regulation. The following exchange between Dr. Hendrie and Subcommittee Chairman Dingell is instructive:
>
> MR. HENDRIE. Mr. Chairman, the intent of the language is to keep NRC's regulatory authority primarily in the field of the nuclear fuel cycle. Not to extend this out into such things as phosphate mining and perhaps even limestone mining which are operations that do disturb the radium-bearing crust of the Earth and produce some exposures but those other activities are not connected with the nuclear fuel cycle, EPA is looking at those and those appear to me to be things that ought to be left to EPA regulation under the Resource Conservation Recovery Act and general authorities.
>
> MR. DINGELL. Your thesis is that we ought not however set up a set of circumstances where we would leave some of these to fall between the cracks and wind up being unregulated.
>
> MR. HENDRIE. I agree fully, Mr. Chairman, and I believe the way the language would cut here, as we recommended, would not leave any crevasse between the two authorities.
>
> Id. at 344. It is clear from this exchange that the definition of "byproduct material" proposed by Dr. Hendrie and adopted by Congress was designed to extend the NRC's regulatory authority over all wastes resulting from the extraction or concentration of source materials in the course of the nuclear fuel cycle.

The Court further stated:

> A construction of section 11(e) (2) is not acceptable if it will orphan mill tailings having a source material content of less than the 0.05% threshold, as is usually the case.

In fact, the Sweetwater uranium mill in Wyoming (which is currently scheduled for reclamation) was licensed and constructed to mill an ore body that had less than 0.05% U_3O_8 (less than 0.0424% U) and in fact throughout its operating life processed uranium ore averaging less than 0.03% U_3O_8. The Sherwood uranium mill in Washington State (now reclaimed) was designed to process ores averaging less than 0.10% U_3O_8, and the average ore grade actually processed during its operational life was likely less than 0.08% U_3O_8 (0.0678% U), with some of the ore being processed likely having a grade of less than 0.05% U_3O_8 (0.0424% U).

As a result, even though the Ore and other monazite sand ores that may be available for processing at the Mill are expected to contain greater than 0.05% U-nat, they do not need to contain that level of U-nat, so long as they are being processed for the recovery of uranium at a licensed uranium mill and it is reasonable to expect that uranium will be recovered, as is the case with the Ore.

It should also be noted that the Ore is natural ore. The steps at Chemours' mines and separation plant do not alter the oxidation state of the natural uranium or other minerals in the excavated sands. The excavated sand grains are typically coated with a film of microbial or other formerly living material settled from the channel or water body where the materials were originally deposited. As discussed in EFRI's letter of June 25, 2020, the mild alkaline/caustic rinse used at the mine simply enables the wash water to better remove the natural biological/organic film from the sand grains. The washing is not conducted at the elevated temperatures, high strength of digestive reagent, or extended contact time necessary to convert the contained minerals within the sand grains. The alkaline wash is incapable of chemically reacting with or changing the oxidation state of uranium or any of the other minerals, nor is that its purpose.

Further, Chemours' separation sequence is not ablation. Ablation uses energy of impact and compression/decompression to spall off or remove the attached mineral coating from the outside of each grain of a mineralized sand. Chemours' sequence does not compress/decompress or remove the minerals from the sand in which, and on which, they are bound. Chemours' sequence only separates sands with different mineral coatings, but each of the separated products is still mineralized sand with the mineral coating attached, as indicated in the flow schematic in Attachment C of EFRI's June 25, 2020 letter (staurolite sand, ilmenite sand, leucoxine sand, rutile sand, monazite sand, among others).

References

WNA, 2019 *Uranium from Rare Earth Deposits* World Nuclear Association September 2019 accessed at https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/uranium-from-rare-earths-deposits.aspx

Kerr-McGee Chemical Corp. v. NRC, 903 F. 2d 1 (D.C. Cir. 1990).

DWMRC COMMENT

RAI 2 – Additional information needed to evaluate potential changes to Mill Tailings Constituent Inventory and concentrations for evaluation of Groundwater Permit Monitoring Requirements

The EFRI letter does not include specific evaluation of the impacts to the mill tailings due to the processing and disposal of the Chemours material tailings. Page 4 of the EFRI letter generally discusses that the Chemours material should not require any additional mill processes; however, *DWMRC notes that monazite sand is not chemically consistent with uranium/vanadium ores from the Colorado Plateau and Arizona Strip which were evaluated when determining compliance monitoring requirements of the Mill in the Groundwater Permit Statement of Basis. Please submit a more detailed EFRI evaluation of the uranium/rare earth mineral ore which will be processed and disposed of in the tailings cells using the anticipated Mill processes (existing or new), including an evaluation of expected changes in constituent concentrations in the tailings management system and potential new constituents which may need to be included in the Groundwater Permit as a result of processing a uranium ore with rare earth minerals.*

EFRI RESPONSE:

The 17 REEs are: cerium (Ce), dysprosium (Dy), erbium (Er), europium (Eu), gadolinium (Gd), holmium (Ho), lanthanum (La), lutetium (Lu), neodymium (Nd), praseodymium (Pr), promethium (Pm), samarium (Sm), scandium (Sc), terbium (Tb), thulium (Tm), ytterbium (Yb) and yttrium (Y).

REEs are all metals. The REEs are collectively referred to as "rare earth metals." The long-term use of REEs as catalysts, and the ever-increasing demand for REEs in magnets, cell phones, batteries, microprocessors, wind turbines, and GPS equipment, among others, are all based on their metal properties, (King, 2018). Historically, they have been referred to as rare earth metals or REMs. Because these elements are frequently used in their oxide form, or in the form of oxide complexes, they are also sometimes referred to as rare earth oxides. For simplicity, for the remainder of this evaluation they will be discussed as metals, and referred to as REEs.

As mentioned in the response to RAI 1 above, Chemours provided uranium and mineral data from seven samples collected during 2019 and 2020, each sample weighting 15 pounds or more. The data, provided in the Attached Table 2, was produced by XRF analysis in Chemours' on-site assay/quality control lab.

As indicated in Table 2, all of the 17 REEs, with the exception of lutetium (Lu) and promethium (Pm), were present in one or more of the samples from the Ore.

Evaluation of the Ore and any Expected Significant Changes in Constituent Concentrations in the TMS

Presence of REEs in Other Uranium Ores. The processing of conventional uranium ores has been adding REEs to the Mill's TMS since the startup of the Mill. Although historically REEs were generally not quantified in uranium resource assessments, REEs are commonly present in uranium ores, including ores from the southwestern United States such as the ores from the Four Corners area and Arizona Strip previously and currently processed at the Mill.

Table 3, Column A, summarizes the ranges of REEs identified in Arizona Strip and Four Corners area (Grants Mineral Belt) ("**AZ/CO**") uranium ores. At least one additional REE not identified in the Ore, lutetium (Lu), is also present at measurable levels in AZ/CO ores. Promethium has not been identified in measurable amounts in the earth's crust, and it has not been identified in the Ore.

It is known to be present only in trace quantities in some uranium ores as a decay product of uranium. Therefore, although the level cannot be quantified and it does not show up on Table 3, it can be assumed that some trace level of promethium is likely present in ores previously processed at the Mill and in the TMS.

Other natural uranium deposits have been documented as containing REEs. For example, the Molycorp Mountain Pass deposit, which is currently the largest rare earth hard rock deposit in the U.S., was first explored as a uranium ore source (Green 2019). This uranium deposit contained areas of 10 to 30% bastnasite (containing the REEs lanthanum, cerium and yttrium) and up to 20% other rare earth minerals in the natural ore prior to processing for concentrations of any mineral. Uranium content ranged from 0.004 to 0.55% uranium. Due to the high REE content and low uranium market price at the time of discovery, it was developed as an REE resource (Olson et. al. 1954). The Bear Lodge deposit in Wyoming is another example of a natural uranium deposit in the American west that has been documented as containing REEs (USGS 2017).

Other examples of REEs being common in conventional uranium ores are: (A) the Stepnogorsk northern Kazakhstan plant, which is under construction to extract the REE dysprosium from conventional uranium tailings (USGS 2017); and (B) in North America in the 1970's and 1980's, Denison Mines, Inc. (a predecessor of Denison Mines Corp., the previous owner of the Mill) recovered the REE yttrium from conventional uranium ore tailings solutions at the Elliot Lake, Canada mill (IAEA 2018). Additionally, in recognition of the fact that REEs are frequently identified in uranium ores, one way of assessing the geologic history of a uranium ore deposit is to track the relative abundances of REEs (Mercadier, et. al. 2011).

Finally, the National Academy of Sciences and USEPA have assumed that highly elevated levels of barium and a range of REEs are normally present in uranium Mill tailings, as a result of their presence in uranium ores (NAS 1986, USEPA 1982).

As a result, Arizona Strip uranium ores processed at the Mill are expected to contain REEs within the ranges indicated in Table 3, and, although not quantified, other uranium ores processed at the Mill from the Colorado Plateau area are also expected to contain REEs generally within the ranges indicated in Table 3.

Assumptions Used to Quantify REEs in Mill Tailings. In the case of other natural uranium ores, EFRI processes the ores for the recovery of uranium, and in some cases vanadium, values. In the case of the Ore, EFRI intends to process the Ore for the recovery of both uranium and an REE Concentrate. Just as is the case in other uranium ore processing, after the economically valuable minerals are recovered (in this case both uranium and REE Concentrate), only the residual solids and solutions will be discharged to the TMS. Therefore, under normal conditions, only a small fraction of the REEs contained in the Ore, expected to be approximately 5%, will be discharged to the TMS from Ore processing. That small fraction of REEs will behave chemically like other metals and mineral components in the TMS.

Although EFRI's June 25, 2020 letter contemplated receipt of approximately 5,000 tons of Ore from Chemours' mines per year over a ten-year period, for purposes of the analysis below, we have assumed annual receipts of 15,000 tons of Ore or similar natural monazite sand ores per year from other sites on an ongoing basis, in order to analyze any potential impacts if the Mill were to receive additional natural monazite sand ores with similar characteristics from other sites in the future. As will be evident from the following analyses, the receipt, processing and disposal of the tailings from 15,000 tons of natural monazite sand ores similar to the Ore per year on an ongoing basis would fall well within the environmental envelop for the Mill and would result in no incremental public health, safety or environmental impacts over and above previously licensed activities. In fact, as demonstrated in this letter, even quantities of Ore or similar natural monazite sand ores double that amount (i.e., 30,000 tons per year on an ongoing basis) could be handled easily and safely at the Mill with no incremental public health, safety or environmental impacts over and above previously licensed activities.

In order to quantify and evaluate the REEs expected to be introduced into the TMS from Ore and similar natural monazite sand ore processing, EFRI has performed the following evaluation assuming all of the conventional ores processed at the Mill to date contained the average REE concentrations listed in Column B of Table 3, and assuming the Mill:

- receives 15,000 tons of Ore or similar natural monazite sand ores per year on an ongoing basis;
- processes 15,000 tons of Ore or similar natural monazite sand ores per year for nine years out of every ten years recovering REE Concentrate and uranium;
- achieves 95% recovery of REEs and discharges 5% of REEs to the TMS for nine years out of each ten-year period;
- to conservatively analyze for any impacts from REEs on the TMS, we have assumed the Mill accumulates but does not process one year of receipts in each ten-year period, i.e. 15,000 tons of Ore or similar natural monazite sand ores are discharged to the TMS unprocessed one year out of each ten years (for example if there were a process upset or if the Mill were to go into reclamation prior to processing the Ore or similar natural monazite sand ore receipts for that year);
- discharges to the TMS 100% of any constituent in the Ore or similar natural monazite sand ore which is not an REE or uranium, assuming the average non-REE constituent concentrations for the Ore or other monazite sand are as set out on Table 2.
- the tailings from processing the Ore and similar natural monazite sand ores are initially deposited in Cell 4A, which is assumed to be filled to capacity with such tailings and other Mill tailings from processing other uranium and uranium/vanadium ores and alternate feed materials over the next ten years (i.e., tailings from processing Ores or other similar natural monazite sand ores totaling 150,000 tons over the next ten years would be deposited in Cell 4A along with tailings from other uranium processing at the Mill, at which time Cell 4A would be completely filled up);
- after Cell 4A is filled up, the tailings from processing Ore and similar natural monazite sand ores are deposited in subsequent tailings cells, each of which is assumed to be filled to capacity with such tailings and other Mill tailings from processing other uranium and uranium/vanadium ores in a ten-year period (i.e., tailings from processing Ores or other similar natural monazite sand ores totaling 150,000 tons over the ten-year period would be deposited in each cell by the time it is completely filled up); and

- under these assumptions, the Mill would receive 15,000 tons of Ore or similar natural monazite sand ore each year over the Mill's life, the tailings from which would be placed into successive tailings cells, with each tailings cell assumed to receive a total of 150,000 tons of such Ore and similar natural monazite sand ores at the time the Cell is filled up and taken out of operation. As a result, the analysis performed for Cell 4A is considered to be representative of the impacts to each successive tailings cell.

As will be evident from the discussion below, the introduction of constituents into the TMS from processing Ore and similar monazite sand ores will not have any impacts on the TMS and is therefore not a concern. Nor would there be a concern if the concentrations of those constituents were higher or the quantity of the Ore or similar monazite sands were higher than the amount assumed for this analysis.

Evaluation of any Expected Significant Changes in Constituent Concentrations in the TMS. The evaluation below addresses the expected composition of tailings and the chemical and environmental behavior of the tailings from the introduction of Ore or similar natural monazite sand ores into the TMS.

Table 4 summarizes the anticipated composition of the tailings solution after processing Ore and similar natural monazite sand ores. The calculations assume that all of the REE content of the Ore or other monazite sand for one year, and 5% of the REE content for nine years, will be discharged to Cell 4A over the remaining ten-year operational phase of Cell 4A, as described above. Cell 4A was used as representative of the receiving tailings cell. Table 4 assumes that the tailings from a total of 150,000 tons of Ore or similar natural monazite sand ores are deposited in Cell 4A and that the remainder of Cell 4A is filled up with other Mill tailings.

The most appreciable change in concentration from processing the Ore or similar natural monazite sand ores will result from barium and zirconium. Although to a much lesser degree, noticeable changes in lead, gallium, hafnium, natural thorium (sometimes referred to in this letter as "**Th-nat**") and certain REEs are also expected. Each of these constituents is not a concern, as detailed below.

(a) Barium (Ba).

Although there should be little barium in the tailings solutions from processing Ore, because it will precipitate with sulfate, for purposes of this analysis, we have assumed all the barium will report to the tailings solutions. Barium has been addressed at length in EFRI's amendment request for Dawn Mining alternate feed material. In addition to the introduction of barium into the TMS with the Dawn Mining material, barium has previously been introduced into the Mill and TMS with the Molycorp alternate feed material, at greater concentrations than are present in the Ore, with no harmful effects to the Mill or TMS. Further, barium chloride is a typical additive to uranium mine water treatment facilities to precipitate radium from the water prior to discharge. Some of those facilities have impoundments which are lined with the same PVC or HDPE liner materials used for the Mill's TMS. High concentrations of barium chloride in those facilities are not considered to result in any degradation to the liners in those systems.

Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, like barium, in all proportions (USEPA 1988). As a result, the introduction of barium into the TMS from processing Ore or in any quantity or proportion is not a concern.

(b) Zirconium (Zr).

Zirconium has been present in the TMS and will behave as all other metals in the tailings solutions. Zirconium has been received and processed in other ores and alternate feed materials, such as the FMRI Metal Resources Inc. ("**FMRI**") material, as indicated in Table 6, and in the Cabot alternate feed material, with no harmful effects to the Mill or TMS. Elevated concentrations of zirconium are not expected to result in degradation to the TMS cell liners. Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, like zirconium, in all proportions (USEPA 1988). As a result, the introduction of zirconium into the TMS from processing Ore or in any quantity or proportion is not a concern.

(c) Lead (Pb).

The Mill has previously processed other feeds with significantly higher concentrations of lead than the Ore with no deleterious effects to the Mill or the TMS. For example, Molycorp alternate feed material contained lead up to 262,400 mg/kg, or more than a 240 times greater lead concentration than the Ore. The license amendment request for the Molycorp alternate feed materials, which was approved by the NRC in 2001, was for 17,750 tons of material. The mass of lead expected to be contributed to the TMS (in Cell 3) from the Molycorp material was therefore up to 4,658 tons of lead compared to the 163.8 tons of lead from 150,000 tons of Ore or similar natural monazite sand ore. Because the majority of tailings from alternate feed materials processed to date have been disposed of in Cell 3, the contribution of lead to tailings from processing Molycorp and other alternate feed materials with elevated lead are not reflected in the quantitative estimate in Table 4. As a result, the 537.2% increase in Mill tailings concentration after Ore processing grossly overstates the impact on the TMS from the addition of lead from the Ore, compared to other ores and alternate feed materials. Were the tailings from the Ore or similar natural monazite sand ore to be placed in Cell 3, the additional contribution to lead in Cell 3 would be insignificant.

Nevertheless, elevated concentrations of lead are not expected to result in degradation to the TMS cell liners. Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, including lead, in all proportions (USEPA 1988). Additionally, the TMS was designed for long-term management of the decay products of the radionuclides disposed of in the Mill tailings. Per the 1997 EA for the Mill, the majority of radionuclides in the TMS will decay to lead, and the TMS is appropriate for long-term management of lead. As a result, the introduction of lead into the TMS from processing Ore or in any quantity or proportion is not a concern.

(d) Gallium (Ga).

Gallium is likely present in the TMS as a result of processing alternate feed materials (such as bastnasite from Molycorp), but has not been analyzed to date. Elevated concentrations of gallium are not expected to result in degradation to the TMS. Gallium will behave like other metals with respect to the tailings cell liners. Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, like gallium, in all proportions (USEPA 1988). As a result, the introduction of gallium into the TMS from processing Ore or in any quantity or proportion is not a concern.

(e) Hafnium (Hf).

Hafnium is likely present in the TMS as a result of processing alternate feed materials, because it is frequently co-present in minerals and mineral slags containing zirconium (such as alternate feed materials from FMRI and Cabot which were known to contain zirconium minerals), but has not been analyzed to date. Elevated concentrations of hafnium are not expected to result in degradation to the TMS. Hafnium will behave like other metals with respect to the tailings cell liners. Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, like hafnium, in all proportions (USEPA 1988). As a result, the introduction of hafnium into the TMS from processing Ore or in any quantity or proportion is not a concern.

(f) Thorium (Th).

Natural thorium is found in low concentrations in uranium ores. Typical sandstone-hosted uranium ores (e.g., Colorado Plateau ores), contain approximately 0.2 to 2.2 pCi/g Th-232 (0.0002 to 0.002% Th-nat). See: NRCP Report No. 118 (1988) and Cardarelli 1999. Other uranium mines in the world have higher natural thorium concentrations. For example, natural thorium concentrations in several uranium mines in Canada have ranged from 0.05% to 0.225%. See CanMet 1977.

The Mill has processed a number of alternate feed materials, including those from Sequoyah Fuels and Heritage Minerals, with elevated levels of thorium. For example, the alternate feed materials from Sequoyah Fuels had a Th-232 range of 1,060-4,990 pCi/g Th-232, with a weighted average of 2,385 pCi/g Th-232, which equates to 0.95% - 4.50% Th-nat, with a weighted average of 2.15% Th-nat. This is comparable to the Ore, which has a range of 2.26% – 3.43% Th-nat, and an average of 3.18% Th-nat. As another comparison, the W.R. Grace alternate feed material, which was approved for processing but was never processed at the Mill for commercial reasons, had a Th-232 concentration ranging up to 31,500 pCi/g, with an average of 8,000 pCi/g Th-232, which equates to a maximum of 28.4% Th-nat and an average of 7.2% Th-nat. The natural thorium content of the Ore is therefore comparable to feed materials processed at the Mill and well within the range of feed materials approved for processing at the Mill.

Historically, natural thorium was not measured on a mass concentration basis in tailings solutions, and activity concentrations of three thorium isotopes, Th-228, Th-230 and Th-232, have only been measured since 2015. Since natural thorium mass concentration was not analyzed in tailings solutions, representative values for natural thorium in tailings were estimated as follows. It was assumed that 7,520 tons of tailings from Sequoyah Fuels alternate feed material, with their average natural thorium content of 2.15% Th-nat, were deposited in Cell 4A. The natural thorium contribution for the remainder of the 2.15 million tons of total tailings capacity in Cell 4A was estimated from the natural thorium value of 0.002% Th-nat from NRCP Report No. 118 for conventional ores, assuming the remainder of the tailings in Cell 4A are all from natural Colorado Plateau ores. Based on this analysis, the estimated total natural thorium content in Cell 4A when full would be approximately 480.8 tons of Th-nat or approximately 0.024% of the total Cell 4A tailings mass. This value is somewhat low because it does not take into account tailings in Cell 4A from any other alternate feed materials with elevated natural thorium levels. By comparison, 150,000 tons of Ore or similar natural monazite sand ore would add approximately 4,762.5 tons of Th-nat to Cell 4A, or approximately 0.24% of the total Cell 4A tailings volume when full.

Although the mass of natural thorium in Cell 4A would increase by 9.9 times, the percentages are very small, and the concentration of Th-nat in the Ore is well within previously approved concentrations and volumes. For example, the W.R Grace alternate feed material amendment application of April 12, 2000, approved by the NRC on December 20, 2000 for processing at the Mill, was for up to 203,000 tons of material, with an average concentration of approximately 7.27% Th-nat. The tailings from the W. R. Grace material were to be deposited in Cell 3. Table 5 shows the impact on disposing of the W. R. Grace tailings in Cell 3, had they been processed at the Mill, assuming Cell 3 was filled to capacity with other ores and alternate feed materials in addition to the W.R. Grace tailings. As evident from Table 5, the total mass of Th-nat contained in the W.R. Grace tailings was estimated to be 14,764 tons or a concentration of approximately 0.54% of the mass of tailings in the cell, which is more than two times the concentration in Cell 4A when full of 0.24% after receipt of tailings from 150,000 tons of Ore or similar natural monazite sand ores over the assumed ten-year operational life of Cell 4A. What this means is that doubling the annual quantity of Ore and similar natural monazite sand ores from 15,000 to 30,000 tons would still fall within the quantity and concentration of Th-nat approved for the W. R. Grace alternate feed material for disposal in Cell 3.

Thorium will behave chemically like other metals with respect to the tailings cell liners. As discussed above, Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts in all proportions (USEPA 1988). As a result, the introduction of natural thorium into the TMS from processing Ore or in any quantity or proportion is not a concern. Management of radiation safety for elevated thorium in the Mill and tailings is addressed in the response to RAI 5, below.

As this analysis assumes that 150,000 tons of Ore or similar natural monazite sand ores are added to each of Cell 4A, Cell 4B and proposed Cells 5A and 5B during their operational lives, and the remainder of each cell is filled to capacity with other Mill tailings, and because each of those cells is approximately the same size, the impact on Cells 4B and proposed Cells 5A and 5B would essentially be the same as the impact analyzed above for Cell 4A. As a result, the Mill could easily process 15,000 tons of Ore or similar natural monazite sand ores on a yearly basis over the Mill's operational life, without any incremental impacts from Th-nat over and above previously licensed activities. In fact, as demonstrated in this letter, even quantities of Ore or similar natural monazite sand ores double that amount (i.e., 30,000 tons per year on an ongoing basis) could be handled easily and safely at the Mill with no incremental public health, safety or environmental impacts over and above previously licensed activities.

(g) REEs

As discussed above, although REEs are not monitored in the TMS, they are known to be present in other ores which have been and will be processed at the Mill, and their content can be estimated. During the period when Cell 3 was being filled with solids (to a capacity of 2,720,000 dry tons), the approximate breakdown of ore tailings vs. alternate feed material tailings, as well as the REE content of ores, is known. If tailings from all the alternate feed materials processed from the inception of the program in 1997, until the time Cell 4A was available to receive tailings, were discharged to Cell 3, alternate feed materials provided only 17% of the tailings discharged to Cell 3. One or two previously-processed alternate feed materials had measurably high contents of REEs, but their actual fraction of the 17% total can only be estimated. Hence, the contribution of alternate feed materials to tailings and to the REE content of Cell 3 was neglected for this calculation, and the REE content was based solely on the ore contribution to tailings. The approximate concentrations of REEs developed for Cell 3 were used to represent the concentration of REEs in Cell 4A. It is assumed that tailings from a comparable ratio of natural ores to alternate feed materials estimated for Cell 3 will be discharged to Cell 4A over its operating life. The current approximate tailings mass and the measured concentrations of other constituents in Cell 4A, as reported in the Mill's annual tailings solutions sampling report, were used to complete the calculations.

Additional information on the REE content of other feeds which have been processed in the Mill are provided in Column J of Table 4 and in Table 6. As mentioned above, since the exact contribution of tailings mass from each alternate feed material can only be approximated, these were not added to the concentration. That is, the concentration of REEs in tailings is likely higher than the values indicated by the methods above.

REEs will behave chemically like other metals with respect to the tailings cell liners. As discussed above, Polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts in all proportions (USEPA 1988). As a result, the introduction of REEs into the TMS from processing Ore or in any quantity or proportion is not a concern.

Evaluation of any potential new constituents which may need to be included in the Groundwater Permit as a result of processing a uranium ore with rare earth minerals

What follows is an evaluation of any potential new constituents which may need to be included in the Mill's GWDP as a result of processing Ore at the Mill.

In the analysis above, we identified appreciable expected changes in concentrations in Cell 4A tailings solutions from barium and zirconium, as a result of Ore or similar natural monazite sand ore processing, with much lesser but still noticeable changes in lead, gallium, hafnium, natural thorium and certain REEs.

As lead is already a constituent included in the GWDP, no further evaluations relating to lead are required. We will therefore address each of the other of these constituents, barium, zirconium, gallium, hafnium, natural thorium and REEs in turn, to determine whether or not they need to be included as monitoring parameters in the GWDP.

Barium. Barium has been addressed at length in EFRI's amendment request for Dawn Mining alternate feed material. As discussed therein, Barium is well-represented by the Mill's current monitoring program. Barium will be chemically the same as magnesium, calcium, and other alkaline earths already introduced into the Mill with other ores and with alternate feed materials. These are currently present in large proportion in the Mill and TMS as discussed in Tables 4 and 6. The Mill currently analyzes tailings and groundwater for calcium and magnesium, which are effective indicators for barium. As a result, there is no need to add barium as a monitoring constituent under the GWDP because of Ore or similar natural monazite sand ore processing.

Zirconium. Zirconium is a transition metal, and typically exhibits a +4 oxidation state. Based on Sheppard et al (2011), the Kd value for zirconium in soils containing low amounts of clay and organic matter (similar to the sandstones hosting perched groundwater at the Mill), is larger than for uranium which is already monitored at the Mill. Uranium is therefore expected to be more mobile than zirconium and would be detected sooner in any potential seepage from the TMS. As a result, there is no need to add zirconium as a monitoring constituent under the GWDP because of Ore or similar natural monazite sand ore processing.

Gallium. As with REEs, discussed below, Gallium exhibits the +3 oxidation state. As discussed in Jensen (2017), gallium is strongly retained by the soil matrix with relatively large Kd values ranging from 400 to 2000. Based on data provided in Sheppard et al, 2011, the Kd for gallium in soils containing low amounts of clay and organic matter (similar to the sandstones hosting perched groundwater at the Mill), is bracketed by the Kd for iron (Fe) and chromium (Cr) which are already monitored at the Mill. In addition, uranium, which is already monitored at the Mill, is expected to be much more mobile than gallium and would be detected sooner in any potential seepage from the TMS. As a result, there is no need to add gallium as a monitoring constituent under the GWDP because of Ore or similar natural monazite sand ore processing.

Hafnium. Like zirconium, hafnium is a transition metal, and typically exhibits a +4 oxidation state. Based on Sheppard et al (2011), the Kd value for hafnium in soils containing low amounts of clay and organic matter (similar to the sandstones hosting perched groundwater at the Mill), are larger than for uranium which is already monitored at the Mill. Uranium is therefore expected to be more mobile than hafnium and would be detected sooner in any potential seepage from the TMS. As a result, there is no need to add hafnium as a monitoring constituent under the GWDP because of Ore or similar natural monazite sand ore processing.

Natural Thorium. Natural thorium, like uranium, is an actinide, and typically exhibits a +4 oxidation state. Natural thorium and thorium 230, the daughter product from the uranium chain, behave the same chemically. Natural thorium and thorium 230 have generally similar chemical behavior as uranium. Based on Sheppard et al (2011), the Kd value for thorium in soils containing low amounts of clay and organic matter (similar to the sandstones hosting perched groundwater at the Mill), is larger than for uranium which is already monitored at the Mill. Uranium is therefore expected to be more mobile than natural thorium and would be detected sooner in any potential seepage from the TMS. Thorium 230, which behaves the same chemically as natural thorium, is prevalent in the Mill's TMS and is not a monitored constituent under the GWDP for these reasons. As a result, there is no need to add natural thorium as a monitoring constituent under the GWDP because of Ore or similar natural monazite sand ore processing.

REEs. REEs include the lanthanides which consist of 15 elements with atomic numbers 57–71 and the chemically similar elements scandium (Sc) and yttrium (Y). The REEs are commonly segregated into light REE (LREE) and heavy REE (HREE) fractions for descriptive purposes, with the separation occurring between europium (Eu) and gadolinium (Gd); Y is most similar to HREE, and Sc is most similar to LREE in solution (Brookins, 1989). A middle REE (MREE) suite is also commonly distinguished, although the specific elements are inconsistently defined between studies.

Weathering of apatite is the most likely source of the general MREE-enrichment in groundwater (Chevis et al, 2015); weathering of accessory minerals, such as apatite, and/or precipitation of LREE-enriched secondary phosphate minerals controls general groundwater REE concentrations and fractionation patterns (Chevis et al, 2015).

General groundwater samples studied in Chevis et al (2015) exhibited broadly similar middle REE (MREE) enriched shale-normalized REE patterns, despite the wide variation in pH of these natural waters ($4.87 \leq pH \leq 8.13$). The similarity of shale-normalized REE patterns across a pH range $4.87 \leq pH \leq 8.13$ suggests that weathering of accessory minerals, such as apatite, and/or precipitation of LREE enriched secondary phosphate minerals controls general groundwater REE concentrations and fractionation patterns (Chevis et al, 2015).

The chemistry of the lanthanides is dominated by the +3 oxidation state. All lanthanide elements form trivalent cations (3+); only Ce(IV) and Eu(II) are stable in oxidation states other than (3+) in aqueous solution under environmentally relevant conditions. Oxidation of Ce(III) to Ce(IV) results in cerium readily precipitating as $CeO_2(s)$; reduction of Eu(III) to Eu(II) results in lower solubility and europium is preferentially incorporated into other minerals (similar to Sr) (Brookins, 1989).

In natural groundwater-aquifer systems, the mobility and transport of REEs are mainly influenced by the amount and type of solution complexing ligands present and the groundwater pH (Noack et al, 2014). Interactions with different mineral phases have been shown to alter REE patterns predictably. For example, an MREE enrichment is observed for freshwater in contact with phosphate-rich minerals (Hannigan and Sholkovitz, 2001; Chevis et al, 2015), while HREE enrichment is found in carbonate-rich waters (Johannesson et al, 1996). Since the solubilities of the REEs are typically low, both surface and solution complexation can be important in fractionating REEs in aqueous solution and their relative importance varies as a function of the overall solution composition (Johannesson and Xiaoping, 1997).

Groundwater pH generally exerts the greatest control over dissolved REE abundance (Noack et al, 2014), with more acidic waters generally containing the most REEs, either via acidification-enhanced weathering or from an enrichment of REE in the acid source (Dia et al, 2000; Gosselin et al, 1992; Gimeno Serrano et al, 2000; Goyne et al, 2010; Ayora et al, 2015; Olías et al, 2018; Verplanck et al, 1999). Under more neutral and alkaline conditions REEs are effectively removed from solution through sorption onto oxides and clays or coprecipitation with carbonates and phosphates by replacing calcium, which has a comparable atomic radius (Bruque et al, 1980; Maza-Rodriguez et al, 1992; Byrne and Kim, 1993; Johannesson et al, 1995; 1996; Coppin et al, 2002; Liu et al, 2017; 2019). Over the pH range 4–8, log dissolved REE abundance follows an approximate −1 slope with increasing pH (Noack et al, 2014).

The REEs exhibit strong complexation with carbonate, particularly as a bicarbonato complex $[REE(CO_3)_2^-]$, and form progressively stronger carbonate and bicarbonato complexes with increasing atomic number (Wood, 1990; Millero, 1992; Johannesson et al, 1995). This behavior is similar to that displayed by uranium.

Inorganic speciation of the REEs in circumneutral pH ($7 \leq pH \leq 9$) groundwaters from the Great Basin indicated REE-carbonate complexes $[LnHCO_3^{2+}$, $LnCO_3^+$ and $Ln(CO_3)_2^-]$ dominate and typically account for more than 99% of each REE in solution; the combined percentage of all REE-phosphate complexes $[LnH_2PO_4^{2+}$, $LnHPO_4^+$, $Ln(HPO_4)_2^-$ and $LnPO_4^0]$ never accounted for more than 0.1% of the dissolved REEs while all other complexes (sulfate, hydroxyl, chloride, and fluoride) and the free metal ion species were predicted to be negligible (Johannesson et al, 1996).

A study developed in 200 Canadian agricultural soils (Sheppard et al., 2009) showed solid-water partition coefficient (Kd) values for REE between 3800 and 8100 L/kg in contrast to Kd values for other metals and metalloids (Zn, Cd, Cu, Cr and As) between 16 and 780 L/kg, showing that a high proportion of REEs are bound to soil in the environment (Sheppard et al, 2009).

Due to the relatively large Kd values, the potential transport of REEs from the TMS is likely to be slower than for other already monitored constituents that are present in the TMS at much higher concentrations. Uranium is expected to be more mobile than the REEs and would be detected sooner in any potential seepage from the TMS. As a result, there is no need to add any of the REEs as monitoring constituents under the GWDP because of Ore or similar natural monazite sand ore processing.

Indicator Parameters. It should also be noted that chloride, fluoride and sulfate are more mobile than any of the foregoing metals and are the best indicator parameters of any potential TMS seepage. As a result, even if any of the constituents analyzed above were not adequately represented in the GWDP by similar metals or other constituents, any potential seepage from the TMS would be adequately monitored by these indicator parameters, because they would all be expected to reach the points of compliance much sooner than any of the metals or other constituents.

Conclusion

The evaluation above addresses the expected composition of tailings and the chemical and environmental behavior of the tailings from the introduction of Ore and similar natural monazite sand ores into the TMS, and considers whether any potential new constituents need to be included in the GWDP as a result of processing Ore and similar natural monazite sand ores at the Mill.

Table 4 summarizes the anticipated composition of the tailings solution after processing Ore and similar natural monazite sand ores. The most appreciable change in concentration from processing Ore and similar natural monazite sand ores will result from barium and zirconium. Although to a much lesser degree, noticeable changes in lead, gallium, hafnium, natural thorium and certain REEs are also expected.

In all cases, our conclusion is that:

- polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, like barium, zirconium, lead, gallium, hafnium, natural thorium and REEs in all proportions (USEPA 1988), and, as a result, the introduction of those constituents into the TMS from processing Ore is not a concern. Nor would there be a concern if the concentrations of those constituents were higher or the quantity of the Ore and similar natural monazite sand ores were higher than the amount assumed for this analysis; and
- lead is already a monitored constituent under the GWDP, and each of the other constituents is well-represented by other constituents which are already analyzed under the GWDP. As a result, there is no need to add any of these constituents as monitoring constituents under the GWDP because of Ore and similar natural monazite sand ore processing.

The conclusions above would apply equally to higher quantities of Ore or similar natural monazite sand ores than the 15,000 tons assumed in the analysis, such as double that amount to 30,000 tons of Ore or similar natural monazite sand ores per year. The only other metals that would show any noticeable increase in tailings if the quantity of Ore or other similar natural monazite sand ores were doubled to 30,000 tons per year are calcium, manganese, and nickel. All are metals which have been introduced to the TMS with other natural ores and/or previously approved alternate feed materials. Calcium, manganese, and nickel are known to be present in natural ores. Like other metals, calcium, manganese and nickel are inert to the tailings liner materials at all proportions and quantities. Calcium, manganese and nickel are monitored in the Mill's groundwater monitoring program.

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DWMRC COMMENT

RAI 3 – Additional information is needed regarding changes or additions that may be required in the uranium extraction circuits

It is unclear in the information submitted where in the process the rare earth minerals would be extracted, and what physical alterations to the mill works would be necessary. Please describe changes necessary to the plant and the processes. If no changes are needed, please explain/justify why not.

EFRI RESPONSE:

Product to be Produced

The Mill will process the Ore (and similar natural monazite sand ores) to recover uranium and an REE Concentrate. The recovered uranium will be sold into the nuclear fuel cycle in the same manner as other uranium produced at the Mill. The REE Concentrate produced at the Mill will be a carbonate that generally contains most of the 17 REEs. The Mill will sell its REE Concentrate to REE separation facilities, where the individual REEs will be separated into individual REE oxides. Those individual REE oxides will then be provided by the separation facility to various end users. For example: neodymium is used to make magnets, which are used in electric motors and sound speakers; yttrium is used in making electrical sensors; catalytic converters use cerium oxides; phosphors in optical displays contain yttrium, europium and terbium oxides; and modern media and communication devices – cell phones, televisions, and computers -- all employ REEs as magnets for speakers and hard drives and phosphors for optical displays. In some cases the REE Concentrate produced by the Mill will be separated at a separation facility into groups of REEs, such as into light REEs (lanthanum, cerium, praseodymium, neodymium, promethium, samarium and scandium) and heavy REEs (yttrium, europium, gadolinium, terbium, dysprosium, holmium, erbium thulium, ytterbium and lutetium) as an intermediate product, for shipment to other facilities, depending on the needs and capabilities of the other facilities, to be separated into actual REEs at those other facilities.

The REE Concentrate that the Mill will produce can be sold in either a dewatered form (approximately 20% moisture content) or in a dry form (approximately 1% moisture content). The Mill currently plans to produce and sell its REE Concentrate in a dewatered form, not a dry form. The currently planned process, which includes dewatering of the REE precipitate, utilizes existing or similar equipment in the same manner it is or could be used for comparable ores and alternate feed materials, involves no air emissions, and will not require any actions under the Mill's existing Air Approval Order. However, the Mill may consider in the future producing all or a portion of its REE Concentrate in a dry form and will evaluate at that time whether any actions under its Air Approval Order may be required in order to dry the REE Concentrate.

Similarly, the Mill may consider in the future performing all or some of the steps required to separate at the Mill individual REEs or groups of REEs from the Mill's REE Concentrate, to produce final or intermediate REE products. Should the Mill decide to go down that path, it would evaluate at that time what if any license or permit amendments or regulatory approvals may be required.

At this time however, the Mill plans to produce only a commercially salable dewatered REE Concentrate.

Process Description

A process description of the uranium and potential REE Concentrate recovery circuits for Ore and similar natural monazite sand ores at the Mill is provided below. As typical for any new ore or alternate feed material, the Mill is currently in the process of optimizing and finalizing the process steps for the Ore and other monazited sands. A generalized schematic flow diagram is provided as Figure 1. The description below and flow schematic represent a potential generic process sequence and configuration. The final process sequence is expected to fall within the envelope of conditions discussed below.

The Ore or similar natural monazite sand ore may be ground via the grizzly and SAG mill, or may be introduced directly into the leach tanks, and once entered into the leach tanks treated ("cracked") with sodium hydroxide ("**NaOH**"). To crack the Ore or similar monazite sand ore, NaOH would be added to the Ore or other monazite sand ore and it would be heated in solution to break down the mineral phosphates, converting them to hydroxides. The solutions would be transferred to a caustic recovery step. Recovered caustic solutions would be returned to the "cracking" step. The Ore or similar natural monazite sand ore would then be washed and the solids would be transferred to the leaching step where they would be leached in hydrochloric acid ("**HCl**") to solubilize the REEs. Tri-sodium phosphate, the byproduct of the caustic recovery, would be discharged to tailings. The Mill already stores and uses tri-sodium phosphate, as well as phosphoric acid, and has introduced phosphate to the TMS over its operating history with no harmful effects. Phosphate, like the other oxygenated anions already present at elevated levels in the TMS and monitored in the TMS and groundwater monitoring program (e.g., sulfate and carbonate), is inert relative to the tailings liner materials. Sodium, as evident in the annual tailings monitoring data, is present in the TMS at times up to 4% or greater, and is also monitored in the groundwater monitoring program.

Following HCl leaching, sodium sulfate ("**Na_2SO_4**") would be added, along with barium chloride ("**$BaCl_2$**") to precipitate radium. The solids would be washed, and the liquid fraction would then be precipitated with sodium carbonate. The rare earth solutions would then be precipitated with sodium carbonate, and dewatered using the Mill's centrifuges or similar equipment, and then packaged. Alternatively, the Mill may evaluate in the future drying the precipitates with low temperature in one of the Mill's existing vanadium dryers or potentially in one or more vacuum dryers that would be installed. Although this drying alternative is not currently planned, and drying is not necessary to produce a salable product, if this alternative is pursued in the future, the Mill would evaluate whether or not any notices or amendments to the Mill's Air Approval Order would be required at that time.

The solids left after the HCl leach would be transferred to the normal uranium circuit for sulfuric acid leaching of uranium. The uranium stream would follow the normal uranium solvent extraction, precipitation and calcining/drying and packaging process used for other uranium ores. The thorium would remain in solution and be disposed of in the TMS.

Alternatively, the Mill may determine that the Ore or similar natural monazite sand ore may be acid leached without caustic cracking. This would mean that the Ore or similar natural monazite sand ore would not need to undergo grinding, and would be directly acid leached. In that scenario, no caustic addition would be required.

Reagents to be Used

The REE process will primarily use reagents which are already used in the Mill for processing conventional ores: Na_2SO_4, soda ash, and NaOH. Following NaOH treatment of the Ore or similar natural monazite sand ore, if that step is necessary, the Mill plans to leach the REEs from the Ore or other monazite sands with an HCl leach. Although the Mill doesn't currently use HCl for leaching, HCl has historically been present in the Mill and is present in the TMS. The Mill has processed a number of alternate feed materials with elevated chloride content, such as Molycorp material, in the acid leach circuit. As soon as those feed materials are introduced into the sulfuric acid leach circuit, chloride ion is converted to HCl and is eventually discharged with other non-uranium constituents to tailings. Chloride ion is also introduced into the TMS from the use of sodium chloride and sodium chlorate, in other parts of the Mill.

Analyses from the annual tailings solution sampling, ranging from several thousand mg/kg up to 10,100 mg/kg (1%) in Cell 4A, or up to 115,000 mg/kg (11%) chloride in Cell 3, demonstrate the Mill has processed and discharged, and the TMS has received and handled, appreciable levels of chloride, much of it in the form of HCl, with no detrimental effects.

The uranium circuit will be unchanged and will use the same reagents as the Mill uses for other ores.

Minimal Equipment Changes

Minimal equipment changes or adjustments would be required.

The Mill anticipates adding an additional storage tank and bermed tank area on site to store HCl. $BaCl_2$ and NaOH (if it is to be used in dry form) will likely be stored in 25Kg bags at the appropriate locations on site. Storage tanks and mixing systems for sodium hydroxide solutions already exist on site. Dewatering will be accomplished using the Mill's centrifuges currently used for vanadium and uranium dewatering, or new centrifuges which could also be used for uranium and vanadium production, or the Mill may use an existing or new filter press or roller press for that purpose.

As mentioned above, the Mill plans to dewater the REE precipitates, and not dry them. However, should the Mill decide in the future to dry the REE precipitates, minimal equipment changes or adjustments would be required. REE drying requires lower temperatures and less energy input than conventional drying. Should the Mill decide to dry the REE precipitates, the Mill would likely either use one of its existing vanadium dryers and vanadium packaging system or install one or more vacuum dryers to dry the precipitated REE Concentrate, which would have their own self-contained packaging systems.

If the Mill were to use one of the existing permitted dryer and air pollution control systems from the vanadium area, it would be heated by existing burners and fuel supply in the same manner as for vanadium drying. REE drying at anticipated production rates is expected to require lower air flow and lower temperature than anticipated in the Mill's Air Approval Order for any of the vanadium dryers at approved vanadium production rates. Similarly, under this alternative, the vanadium packaging system and packaging baghouse stack would be utilized.

Unlike the Mill's current dryers and packaging systems, if a vacuum dryer system were to be installed, it would not use direct fired heating (no open-hearth burners), and neither the dryers nor the packaging system would exhaust combustion gases to the atmosphere (no process emissions stacks). Combustion gases from the heating source would be exhausted where the steam or indirect heating fluid is heated, and the vacuum dryers would utilize existing Mill heating sources. A typical vacuum dyer loop and packaging system would contain:

- Indirect pre-heating: (heating steam or other indirect heat source)

- Rotary vacuum dryer;
- Vapor treatment or recovery: High Efficiency Particulate Air ("**HEPA**") bag filter, water scrubber, and vapor condenser;
- Cooling water for vacuum pump sealant water; and
- Packaging equipment, controlled by the same vacuum system and vapor treatment as the dryer.

As mentioned above, drying is not required to produce a salable product, so the Mill currently plans to dewater, not dry, the REE precipitate, and then package the dewatered precipitate for transport to an REE separation facility. Should the Mill decide to dry the REE precipitate in the future, it would evaluate at that time whether or not any actions under its Air Approval Order may be required.

Standard Operating Procedures

The Mill will amend its existing Standard Operating Procedures ("**SOPs**") and adopt any new SOPs that may be required in connection with the foregoing process changes and adjustments.

The process changes and adjustments described above, and any changes to existing SOPs and adoption of any new SOPs fall within the range of normal process change activities that are reviewed and approved by the Mill's Safety and Environmental Review Panel ("**SERP**") on a routine basis. The Mill plans to have its SERP review and approve all such process changes, adjustments, revised SOPs and new SOPs prior to commencement of each of the applicable Ore receipt, handling, storage, processing, drying packaging and disposal activities.

Air Approval Order

The currently planned process, which includes dewatering the REE precipitate, utilizes existing or similar equipment in the same manner it is or could be used for comparable ores and alternate feed materials, involves no air emissions, and does not involve: (a) constructing any new installations which will or might reasonably be expected to become a source or an indirect source of air pollution; (b) making any modifications to or relocating any existing installations which will or might reasonably be expected to increase the amount of, or change the effect of, or the character of, air pollutants discharged, so that any such installation may be expected to become a source or indirect source of air pollution, or (c) installing any control apparatus or other equipment intended to control emissions of air pollutants. As a result, no notifications, approvals or amendments are required under the Mill's existing Air Approval Order for the production of a dewatered REE Concentrate at the Mill.

Should the Mill decide to evaluate drying the REE precipitate at the Mill in the future, the following factors would be relevant. The Mill anticipates having sufficient steam production capacity within its existing boilers on site to provide pre-heating for one of the existing vanadium dryers, or a vacuum dryer, without new combustion equipment. If the Mill uses one of the existing permitted vanadium dryers and the existing vanadium scrubber system, all air emissions from the dryer would be addressed by the vanadium scrubber system, in the same manner as for vanadium drying, and the vanadium packaging system and packaging baghouse stack would be utilized to address any air emissions from packaging. In the case of vacuum drying, moisture and vapors removed by the vacuum dryers would not be exhausted to air, but would be vented into one or more of the particulate control equipment items identified as "vapor treatment or recovery," above. For either drying option, EFRI would evaluate whether any changes to the Mill's air emission inventory or Air Approval Order would be required, based on the configuration and throughput rate ultimately selected for the dryer, packaging, and air pollution control system, and would provide any required notices or requests for approval to the Utah Division of Air Quality on a timely basis.

DWMRC COMMENT

RAI 4 – Additional information for compliance with U.S. Department of Transportation requirements

On June 26, 2020 in an email request, the Division requested to see an old manifest of the monazite sand material when it was being sent to China. After reviewing both the letter of June 25, 2020 and the manifest please provide the following information:
U_3O_8

- *The manifest provided listed the "chemical form" as monazite sand. This is not a chemical form description according to U.S. Department of Transportation. Please provide the correct chemical form for the uranium/rare earth mineral ore. (i.e.* U_3O_8 *other appropriate chemical descriptions).*

- *In the EFRI's letter it states that Supersacks in intermodal containers will be used to transport the uranium ore to the Mill. Please provide information that the Supersacks and intermodal containers are IP-1 containers which are the appropriate transport containers for LSA-1 material.*

- *Please indicate the shipment of the uranium/rare earth mineral ore will be exclusive use shipments.*

- *Please provide a detailed description of transportation route(s) that will be used to transport the ore to the Mill.*

- *Please update the transportation emergency response plan to include the transportation of the uranium/rare earth mineral ore from Georgia to the Mill.*

- *Please provide a description of all other transportation requirements regarding labeling, placarding, transportation papers, etc.*

EFRI RESPONSE:

Shipments of Ore to the Mill

The following discussion addresses how the Ore will be shipped to the Mill. It is expected that if any other natural monazite sand ores are to be shipped to the Mill, similar transportation factors would apply.

Manifest. Chemours may ship the Ore either by rail in inter-modal containers ("**IMCs**") or other LSA-1 approved containers or by truck, as discussed below. For the purposes of U.S. Department of Transportation ("**DOT**") documentation, the Ore will be labeled with chemical form "Natural Uranium (U-nat) and Natural Thorium (Th-nat)." EFRI will work with Chemours to ensure the Ore is properly labeled on the manifest and other shipping documentation.

IP-1 Containers to be Used. The Ore will be shipped as Radioactive LSA-1 (low specific activity) Hazardous Material as defined by DOT regulations. Chemours will ship the Ore in Supersacks that meet IP-1 packaging requirements and are appropriate for LSA-1 Class 7 material. Whether the Ore is shipped in IMCs or other LSA-1 approved containers or by trucks, the IMCs, other LSA-1 approved containers or trucks will be suitable containers for LSA-1 Hazardous Material. The IMCs or other LSA-1 approved containers will provide secondary containment to prevent any breaches of the Supersacks.

Exclusive Use Shipments. Each shipment will be "exclusive use" (i.e., the only material on each vehicle, IMC or other LSA-1 approved container will be the Ore, unless and until the vehicle, IMC or other LSA-1 approved container is decontaminated for free release in accordance with applicable Mill procedures).

Transportation Routes. Chemours may ship the Ore by either of the following methods. Chemours would load the Ore Supersacks into IMCs or other LSA-1 approved containers at its Offerman site. Chemours' transportation contractor would load the IMCs or other LSA-1 approved containers onto rail cars at the railhead at the Offerman site. The IMCs or other LSA-1 approved containers would be transported by rail to one of the existing rail transfer yards in Utah (e.g., Crescent Junction or Green River), followed by transfer to intermodal truck tractors from the railhead to the Mill. The Ore would be hauled by truck along U.S. Highway 191 to the Mill.

Alternatively, the Ore Supersacks may be loaded onto trucks at the Offerman Site. The trucks would travel via surface roads to I-95 and north along I-95 to I-40. They would follow I-40 to Albuquerque, then use surface roads from I-40 to the Mill. The route may vary depending on road conditions and weather.

At full capacity, the Mill receives and processes approximately 2,000 tons of ore per day, or up to 720,000 tons of ore per year. 15,000 tons of Ore or similar natural monazite sand ore per year, or double that amount, would be an insignificant portion of the Mill truck traffic when the Mill is in full operation, and no impacts to local traffic over and above those already contemplated for normal Mill truck traffic are expected.

<u>Transportation Emergency Response Plan.</u> Chemours' transportation contractor has an Emergency Response Action Plan ("ERAP") in place for the Ore. The ERAP will be adapted based on the transportation method (road or rail) chosen.

As discussed above under EFRI's response to RAI 2, the Ore has a uranium content comparable to Colorado Plateau ores and a natural thorium content comparable to previously approved alternate feed materials (e.g., Sequoyah Fuels), and contains no additional constituents of any significance beyond those associated with other ores or alternate feed materials previously transported to the Mill. Therefore, the Ore poses no additional hazards during transport above previously licensed activities. Existing accident response and spill response procedures are therefore sufficient for management of potential transportation accidents or spills of the Ore.

<u>Marking, Labeling and Placarding.</u> Chemours will arrange with its transportation contractor for the proper marking, labeling, placarding, manifesting and transport of each shipment of Ore. Each shipment or container will include:

- Bill of lading;
- Safety Data Sheet;
- DOT Emergency Response Plan (Spill Guide);
- Radiological Release Form (from the Chemours site);
- Packing List;
- Emergency Contact Information;
- Route Instructions; and
- Placard/Labeling as UN2912 Radioactive 7.

Shipments will be tracked by the transportation contractor from the Offerman plant until they reach the Mill.

Shipments of REE Concentrate from the Mill.

<u>Manifest.</u> The Mill will ship its REE Concentrate in enclosed sea containers by truck to a seaport, likely Seattle, San Francisco or Houston, depending on whether or not the REE Concentrate will be shipped to Asia or Europe, or alternatively to a point of final destination in North America, or by truck part way and by rail for the remainder of the distance. For the purposes of DOT documentation, the REE Concentrate will be labeled with chemical form "Rare Earth Carbonate."

<u>IP-1 Containers to be Used.</u> The dewatered REE Concentrate will be shipped according to DOT regulations. The Mill will ship the dewatered REE Concentrate in Supersacks that meet IP-1 packaging requirements with an inner plastic sealed liner, or in sealed 55-gallon drums or other sealed containers. The containers will meet DOT shipping standards. The enclosed sea containers will provide secondary containment and protect the Supersacks from breach. The shipment of dewatered metal product without drying has previously been evaluated for the Mill. The original

1978 Environmental Report for the Mill contemplated that from certain ores, the Mill would produce and ship a moist filter cake of copper that would be transported to an offsite facility for drying.

Not Exclusive Use Shipments. Each shipment of REE Concentrate will be free-released from the Mill and will not be "exclusive use".

Transportation Routes. The lined Supersacks, drums or other sealed containers will be loaded into enclosed sea containers at the Mill and shipped by truck on Highway 191 either north to I-70 or south on public roads to I-40 to the seaport or final destination, or may be transferred to rail at some point along the route.

At full capacity, the Mill receives and processes approximately 2,000 tons of ore per day, or up to 720,000 tons of ore per year. The REE Concentrate produced from 15,000 tons of Ore and similar natural monazite sand ore per year, or double that amount, would be an insignificant portion of the Mill truck traffic when the Mill is in full operation, and no impacts to local traffic over and above those already contemplated for normal Mill truck traffic are expected. Likewise, the REE Concentrate would be an immeasurably small addition to regional rail freight if a segment of its transport involved rail.

Transportation Emergency Response Plan. The Mill's transportation contractor will have an Emergency Response Action Plan ("ERAP") in place for the REE Concentrate. The ERAP will be adapted based on the transportation method (road or road/rail) chosen.

Marking, Labeling and Placarding. The Mill will arrange with its transportation contractor for the proper marking, labeling, placarding, manifesting and transport of each shipment of REE Concentrate. Each shipment or container will include:

- Bill of lading;
- Safety Data Sheet;
- DOT Emergency Response Plan (Spill Guide);
- Radiological Release Form (from the Mill);
- Packing List;
- Emergency Contact Information;
- Route Instructions;
- Labeling with shipper information and content on each drum or bag; and
- Placard/Labeling as required by DOT.

Shipments will be tracked by the transportation contractor from the Mill until they reach their final destination.

DWMRC COMMENT

RAI 5 – Assess the Radiological and Non-radiological effects of processing uranium ore with rare earth minerals

From the 1978 Environmental Report for the White Mesa Uranium Project, Section 1.0 Proposed Activities, it states "Energy Fuels Nuclear, Inc. proposes to construct and operate an acid leach uranium mill-and associated facilities for producing yellowcake uranium concentrate and, when economically feasible, limited quantities of copper and/or vanadium concentrates." In EFRI's June 25, 2020 letter, it proposes to process a uranium ore for yellowcake uranium concentrate and a rare earth mineral concentrate. The process of extracting a rare earth mineral concentrate has not been environmentally evaluated for the White Mesa Uranium Mill.

Please evaluate the radiological and non-radiological effects of processing a uranium ore with rare earth minerals. Please include occupational and public exposure and short and long-term effects of processing uranium ore with rare earth minerals.

Please discuss any adjustments needed to the radiation safety program, environmental monitoring program and groundwater monitoring to process the ore. If no changes are needed, please explain/justify why not.

EFRI RESPONSE:

All the Material Processes Applicable to Extracting an REE Concentrate at the Mill have Previously been Environmentally Evaluated.

The Mill is a licensed uranium processing facility that has processed to date over 5,000,000 tons of uranium-bearing conventionally mined ores and alternate feed materials mainly for the recovery of uranium and vanadium, and is also licensed to recover and has recovered tantalum and niobium (from the Cabot alternate feed materials), in all cases with the resulting tailings being permanently disposed of as 11e.(2) byproduct material in the Mill's TMS. Environmental impacts associated with such previously licensed Mill operations have been thoroughly evaluated and documented in the past. See, for example:

- the original 1979 Final Environmental Statement ("**FES**") for the Mill;
- Environmental Assessments ("**EAs**"), dated 1985 and 1997;
- an EA for the Mill's reclamation plan dated 2000;
- EAs for alternate feed materials dated 2001 and 2002, in each case prepared by the NRC;
- the Safety Evaluation Report for the Receipt, Storage and Processing of FMRI Alternate Feed Material prepared by DWMRC;
- the Safety Evaluation Report for the Receipt, Storage and Processing of Dawn Mining Alternate Feed Material prepared by DWMRC;
- the Safety Evaluation Report for the Receipt, Storage and Processing of Sequoyah Fuels Alternate Feed Material prepared by DWMRC; and

- The Technical Evaluation and Environmental Assessment Report prepared in connection with the 2018 Radioactive Materials License Renewal for the Mill, prepared by DWMRC.

The Ore or similar natural monazite sand ore will be processed at the Mill for the recovery of uranium and an REE Concentrate and the resulting tailings will be permanently disposed of in the Mill's tailings impoundments as 11e.(2) byproduct material, in a similar fashion as other conventionally mined ores and alternate feed materials that have been processed or licensed for processing at the Mill.

Accordingly, the discussion below will focus on the various pathways for potential radiological and non-radiological impacts on public health, safety and the environment and determine if the receipt and processing of the Ore or similar natural monazite sand ores would result in any potential significant *incremental* impacts over and above previously licensed activities.

Potential effects on existing tailings or the TMS, and potential impacts on groundwater were discussed in the response to RAI 2, above. The pathways that are analyzed in the discussion below are the following:

a) potential impacts from transportation of the Ore or similar natural monazite sand ores to the Mill;
b) potential impacts from radiation released from the Ore or similar natural monazite sand ores while in storage at the Mill;
c) any chemical reactions that may occur in the Mill's process;
d) potential impacts on surface water;
e) potential airborne radiologic impacts;
f) potential radon and gamma impacts; and
g) worker health and safety issues.

These potential pathways will be discussed in the following sections of this letter.

The findings below will demonstrate that, because all the constituents in the Ore have either been reported to be, or can be assumed to be, already present in the Mill's TMS or were reported in other conventional ores or licensed alternate feed materials, at levels generally comparable to or higher than those reported in the Ore, the resulting tailings will not be significantly different from existing tailings at the facility, and the impacts from the foregoing pathways will not be significantly different from the Ore or similar natural monazite sand ores than from other conventional ores and licensed alternate feed materials. Consequently, there will be no incremental public health, safety or environmental impacts over and above previously licensed activities. *As a result, although not expressly evaluated in previous analyses, the process of extracting an REE Concentrate has in fact been environmentally evaluated for the Mill, through the evaluation of similar activities.*

The radiological and non-radiological effects of processing a uranium ore with rare earth minerals

Occupational Exposure – Analysis of any Radiological Effects. The uranium concentration, which will generally be in equilibrium with its daughters because the Ore has not been chemically altered in any way, is comparable to a typical Colorado Plateau uranium or uranium/vanadium ore, and significantly less than a typical Arizona Strip ore. As a result, occupational exposures from uranium and its daughters associated with processing the Ore and similar natural monazite sand ores will not be any different from occupational exposures from Colorado Plateau ores, and will easily be addressed within the Mill's normal radiation protection SOPs.

The natural thorium concentration in the Ore, which is also expected to generally be in equilibrium with its daughters because the Ore has not been chemically altered in any way, is higher than for Colorado Plateau and Arizona Strip ores, but well within the concentrations of natural thorium contained in previously licensed alternate feed materials. Specifically, it is comparable to the natural thorium concentrations contained in the Sequoyah Fuels alternate feed materials, which have been successfully and safely received and processed at the Mill, and well below the natural thorium concentrations in the W.R Grace alternate feed materials, which were licensed for processing at the Mill but never received or processed, for commercial reasons. The Mill maintains in place, and updates from time-to-time, a "High Thorium Content Ore Management" SOP for handling ores and feed materials with elevated levels of thorium, which was originally implemented in connection with the approval of the W.R. Grace alternate feed material license amendment, and was approved by the NRC. The applicable provisions of that SOP are adapted to prepare feed-specific SOPs for any ores and alternate feed materials with elevated levels of thorium, and has been used in the past to prepare feed-specific SOPs for alternate feed materials such as Sequoyah Fuels and Heritage. The Mill will prepare an Ore-specific SOP, in the same manner as specific SOPs have been adopted for handling feed materials with elevated levels of thorium in the past. The radiation protection procedures in the Ore-specific SOP are expected to be similar to those in the Sequoyah Fuels-specific SOP, because the natural thorium content of the Ore is similar to the natural thorium content of the Sequoyah Fuels material.

As discussed above and in EFRI's letter of June 25, 2020, the Ore will be shipped to the Mill in Supersacks in IMCs or other LSA-1 approved containers. Trucks arriving at the Mill site will be received according to existing Mill procedures. The Supersacks will be unloaded from the trucks onto the ore pad for temporary storage until the material is scheduled for processing. The Ore will remain within the Supersacks while stored on the ore pad. Maintaining the Ore in the Supersacks pending processing will prevent any windblown dust from emanating from the Ore. Further, the Ore is dry (expected to have 0.5-1.0% moisture content), and by maintaining the Ore in the Supersacks pending processing any water infiltration will be prevented, all of which means that there will be no chance of any moisture seepage out of the Supersacks while on the Ore pad. Because the Ore does not significantly differ in radiological activity from other ores and alternate feed materials, and because the Ore will be stored in Supersacks on the Mill's ore pad pending processing, there will be no environmental impacts associated with the Ore or similar natural monazite sand ores over and above those associated with other ores and alternate feed materials handled at the Mill on a routine basis.

Occupational Exposure – Analysis of any Non-Radiological Effects. As discussed above, the REEs and heavy metals in the Ore are already present in uranium ores historically and currently processed at the Mill.

Experience at Chemours' Offerman separation plant has determined that the Ore is stable under ambient environmental conditions and does not require any special handling. The only potential operational exposure to dust would be associated with unloading the Supersacks into the grizzly, if that process sequence were to be selected. Dust protection measures already in place for processing of other ores and alternate feed materials will be sufficient for the management of dust hazards from REEs during introduction into the grizzly. If the Ore is introduced into the Mill process by a means other than the grizzly, such as directly into the leach tanks, suitable dust suppression measures as well as worker PPE equipment will be utilized as required to meet all radiological and occupational protection requirements. For the production of a dewatered REE Concentrate, as currently planned, all subsequent steps in the Mill will be wet processes with no dust generation and no pathway for worker exposure over and above normal Mill operations. Should the Mill produce a dried REE Concentrate in the future, the level of worker respiratory protection needed for conventional or vacuum dryer operations and packaging, is already in place at the Mill for vanadium and yellowcake drying and packaging.

The following additional reagents are expected to be used in the REE recovery process:

- HCl solution;
- Barium chloride; and
- Barium sulfate.

Although HCl is currently not added to the Mill circuits, it is already circulating in the Mill. The introduction of alternate feed materials with high chloride content into the acid leach system generates HCl upon contact with sulfuric acid. For example, Molycorp alternate feed material had up to 89,900 mg/kg (9%) chloride, and several alternate feed materials that continue to be received and processed have comparable levels of chloride. Since its inception, the Mill has also stored and used high strength HCl in the lab. The Mill also adds chloride ion in the form of sodium chlorate, and sodium chloride in other parts of the Mill. Appreciable quantities of sodium chloride are added to the uranium SX for processing specific (acidic) solutions. An indication of the level of HCl in circulation is the approximately 40 g/L of chloride measured in the Cell 1 evaporation cell at acidic pH levels, as a result of this SX process.

Hence, the Mill has introduced chloride and managed HCl in the Mill circuits, Lab and TMS on a routine basis. Existing SOPs and worker protection measures for the aggressive reagents such as sulfuric acid used by the Mill on a regular basis are more than sufficient for worker protection from HCl in solutions.

Barium will be chemically the same as magnesium, calcium, and other alkaline earths already introduced into the Mill with other ores and alternate feed materials. These are currently present in large proportion in the Mill and TMS as discussed in Tables 4 and 6.

Due to the use of sulfuric acid leaching, both the acid leach circuit and the TMS are essentially acid sulfate systems with sulfate levels orders of magnitude greater than will be added with barium sulfate reagent.

In summary, each of the REE process reagents:

- is already used and stored at the Mill;
- has already been circulated within the Mill after being with other ores or alternate feed materials; or
- is generated and managed in the Mill as part of normal uranium recovery chemistry in the Mill.

As a result, for each of the reagents:

- the Mill already has appropriate worker safety protection in place; and
- the chemical is already present in the tailings.

Public Exposure – Analysis of any Radiological and Non-Radiological Effects. As discussed above and in EFRI's letter of June 25, 2020, the Ore will be shipped to the Mill in Supersacks in IMCs or other LSA-1 approved containers. The Ore will remain within the Supersacks while stored on the ore pad. The Supersacks will be inspected and cover or other measures will be applied if deterioration of the fabric or seams is detected. If the Ore is introduced into the Mill process by a means other than the grizzly, such as directly into the leach tanks, suitable dust suppression measures as well as worker PPE equipment will be utilized as required to meet all radiological protection requirements. Once the Ore is fed into the Mill process, there will be no other pathway for public exposure from the REEs. If an existing vanadium dryer, scrubber, packaging system and baghouse are used to produce dried REE Concentrate in the future, emissions would be controlled in the same fashion as emissions from vanadium production. If vacuum dryers were to be used, they would have no emission stack and could not generate off-site emissions. The natural thorium will be removed to tailings prior to precipitation of the uranium. The recovered uranium will be precipitated, dried and packaged in accordance with existing Mill SOPs, which address exposures to the public from uranium and its daughters.

As a result, because of the absence of pathways to public exposure to the Ore or similar natural monazite sand ores during receipt, storage, introduction into the Mill process, processing, drying, packaging and tailings disposal, there will be no additional short term or long-term effects to the public from non-radiological constituents in the Ore or similar natural monazite sand ores, or its processing and tailings management over and above existing licensed operations at the Mill.

Further, since no significant physical changes to the Mill circuit and no new types of process chemicals that are inconsistent with existing Mill operations will be necessary to process the Ore or similar natural monazite sand ores, no significant construction impacts beyond those previously assessed will be involved.

Short and long-term effects of processing uranium ore with rare earth minerals.

The discussion above addresses both short- and long-term effects of processing uranium ore with REEs in the context of occupational and public exposures from radiological and non-radiological factors. The following discussion focuses on the short-term and long-term effects on the TMS and closure and reclamation.

Short-term and Long-term Effects on Tailings Management System. Processing the Ore or similar natural monazite sand ores will have no effects beyond those identified in the approved FES, EAs, Safety Evaluation Reports, Technical Evaluation Reports and Reclamation Plans on tailings operational management and closure. The Ore or similar natural monazite sand ores will have no effect on existing approved plans for decommissioning of the Mill, buildings, land or structures, or reclamation of the site. The Ore or similar natural monazite sand ores will have no effect on tailings design components addressing permanent isolation of tailings, slope stability, settlement or liquefaction of reclaimed tailings, or design features addressing disposal cell covers or erosion protection.

As discussed above, Table 4 summarizes the anticipated composition of the tailings solution after processing Ore or similar natural monazite sand ores. The most appreciable change in concentration from processing Ore or similar natural monazite sand ores will result from barium and zirconium. Although to a much lesser degree, noticeable changes in lead, gallium, hafnium, natural thorium and certain REEs are also expected.

In all cases, our conclusion is that polymeric materials such as PVC and HDPE are selected for geomembrane liners specifically because they are resistant to solutions of metals and metal salts, like barium, zirconium, lead, gallium, hafnium, natural thorium, and REEs in all proportions (USEPA 1988), and, as a result, the introduction of those constituents into the TMS from processing Ore or similar natural monazite sand ores or in any quantity or proportion is not a concern.

Mill Tailings Closure and Reclamation. Because radionuclide content is within the ranges associated with other ores and alternate feed materials approved for processing at the Mill, there will be no effect on radon attenuation, gamma attenuation or TMS cover design.

Elevated concentrations of Th-nat in the tailings will not impact tailings cover design. Radon-222 from the uranium chain and radon-220 (thoron) from the natural thorium chain are the gaseous radioactive products of the decay of the radium isotopes radium-226 from the uranium chain and radium-224 from the natural thorium chain, for radon-222 and radon-220, respectively. The UNSCEAR 2000 Report (Annex B) notes that, the radioactive half-lives of radon and thoron and their respective decay products are very important in determining their behaviour in the environment. Since thoron has a much shorter half-life ($t_{½}$ = 55 sec) than radon ($t_{½}$ = 3.82 days), the distance thoron can travel before undergoing radioactive decay is very much shorter than the distance radon can travel in the same medium. This is important with respect to consideration of effectiveness of tailings covers.

To illustrate, consider that thoron (Rn-220) has a much shorter half-live (of 55.6 s) and hence the distance that thoron can diffuse before decaying to a solid isotope is very much smaller than for Radon (Rn-222). To illustrate, the diffusion length (see UNSCEAR 2000) is given by:

$$L = \sqrt{\frac{D}{\lambda P}}$$

where

D is the bulk diffusion coefficient (m^2/s)
λ is the decay constant (s^{-1})

- $\lambda_{Rn} = 2.1 \times 10^{-6}\ s^{-1}$
- $\lambda_{Tn} = 1.25 \times 10^{-2}\ s^{-1}$

P is the porosity.

The ratio of the diffusion lengths of thoron to radon can be estimated as

$$\frac{L_{Th}}{L_{Rn}} = \sqrt{\frac{\lambda_{Rn}}{\lambda_{Th}}} = \sqrt{\frac{2.1 \times 10^{-6}}{1.25 \times 10^{-2}}} \approx \frac{1}{77}$$

Thus, a cover effective for radon-222 will be nearly 80 times more effective at reducing thoron.

As the concentration of Th-nat in Cell 4A after processing 150,000 tons of Ore or similar natural monazite sand ores from Table 4 is 5,243.3/2,150,000, the activity of Th-232 and each of its daughters, including thoron, will be 268 pCi/g. By contrast, Cell 4A, if completely filled with Colorado Plateau uranium ores would contain approximately 875 pCi/g Th-230 (see Abdelouas 2006) and hence 875 pCi/g Ra-226 and 875 pCi/g Rn-222 in equilibrium. The additional thoron from the Ore and similar natural monazite sands would only add about the equivalent of 268/77 = 3.5 pCi/g to the already existing Rn-222 activity in the tailings cell of 875 pCi/g, which would be insignificant to the cell cover design. Also, since the uranium content of the Ore is comparable to Colorado Plateau ores, the Th-230 content of the Ore is comparable to Colorado Plateau ores and would not add an additional source term for Ra-226 to the tailings, as the Th-230 decays into Ra-226 over time, over and above tailings from Colorado Plateau ores.

The natural thorium chain emits gamma, similar to the gamma emitted from the Ra-226 in the uranium chain. Gamma rays from uranium and thorium decay chains are attenuated in the same fashion by cover materials such as used on tailings impoundments. For practical purposes, gamma rays are reduced by a factor of about 2 for each 10 cm of cover material. The gamma rays from the Th-232 decay chain are attenuated similarly to the gamma rays from Ra-226 (i.e., the gamma rays from the U-238 decay chain). Thus, a cover appropriate for shielding Ra-226 gammas is also appropriate for shielding gammas from the Th-232 decay chain. The radon barrier on a closed out tailings area would attenuate gamma rays from either Ra-226 or the Th-232 decay chain.

For estimating the attenuation provided by packed earth covers over an extended radioactive source, such as a tailings pile, the EPA (US EPA1982) uses the following equation and a half-value layer (HVL) of 0.04 m (= 4 cm): for every 4 cm of cover, the gamma radiation is attenuated by a factor of 2.

Calculations can be done with Microshield™. If we assume a soil cover with densities of 1.6 g/cm^3 and 2.0 g/cm^3, the gamma transmission factors for various thicknesses of soil cover (above a planar Ra-226 source) are shown in the following table.

Gamma Transmission Through Soil Covers

Soil Cover	Cover Transmission Factors	
(cm)	$\rho = 1.6$ g/cm^3	$\rho = 2.0$ g/cm^3
0	1	1
5	5.1E-01	4.4E-01
10	2.9E-01	2.3E-01
20	1.1E-01	6.7E-02
50	7.8E-03	2.9E-03
100	1.7E-04	2.7E-05

The soil cover of the current reclamation plan ET cover design for Cell 4A is 9.5 feet (289.56 cm) thick, so gamma is effectively attenuated to zero by the cover design.

When 150,000 tons of Ore and similar natural monazite sand ores are added to Cell 4A, the thorium-232 content will be 2,439 ppm (Table 4) or about 0.24% Th-nat, which equates to about 270 pCi/g Th-232, compared to the Ra-226 content of about 875 pCi/g, assuming Cell 4A is comprised primarily of Colorado Plateau ores and about 1,680 pCi/g assuming Cell 4A is comprised primarily of Arizona Strip Ores. Doubling the amount of Ore or similar monazite sand ores in Cell 4A would increase the concentration of Th-nat to 0.48% and would result in an average activity from Th-232 of approximately 540 pCi/g, which when added to the 875 pCi/g assumed for Cell 4A in Table 4, would be less than the activity from a tailings Cell comprised primarily of tailings from Arizona Strip ores which is possible under the Mill's current license. Even with this doubled amount of Th-nat in Cell 4A, the added gamma from the Th-nat would be insignificant relative to the gamma fields associated with normal uranium ores, and in any event, the thickness of the cover would reduce all of these gamma emissions effectively to zero. As a result, the addition of Ores and similar natural monazite sand ores to the Mill's TMS will not impact cover design

Because processing the Ore or similar natural monazite sand ores and disposing of the tailings in the TMS will not affect cover design at closure and reclamation, there will be no effect on the final radon barrier design or its method of emplacement. Processing Ore and similar natural monazite sand ores will have no effect on completion of the final radon barrier or on the timetable for completion of reclamation.

Because processing Ore and similar natural monazite sand ores will have no effect on reclamation and closure design, construction or timing, it will have no effect on existing and approved financial surety estimates or arrangements, and will not require any changes to costs of long-term surveillance.

No Adjustments Needed to the Radiation Safety Program

As discussed above under "Occupational Exposure – Analysis of any Radiation Effects", the uranium concentration in the Ore is comparable to a typical Colorado Plateau uranium or uranium/vanadium ore, and significantly less than a typical Arizona Strip ore. As a result, occupational exposures from uranium and its daughters will not be any different from occupational exposures from Colorado Plateau ores, and will easily be addressed within the Mill's normal radiation protection SOPs.

The Ore contains concentrations of natural thorium that are elevated compared to conventional ores but comparable to the concentrations in alternate feed materials, such as Sequoyah Fuels that have been processed at the Mill. In accordance with the Mill's existing radiation protection program, and as typical for any new types of ores or alternate feed materials, the Mill will prepare an Ore-specific SOP. The Ore-specific SOP will be developed in the same manner as specific SOPs have been adopted for handling feed materials at the Mill with elevated thorium levels in the past, and will include application of the relevant provisions of the Mill's High Thorium Content Ore Management SOP. The radiation protection procedures in the Ore-specific SOP are expected to be similar to those in the Sequoyah Fuels-specific SOP, because the natural thorium content of the Ore is similar to the natural thorium content of the Sequoyah Fuels material. The Ore-specific SOP will be reviewed and approved by the Mill's SERP, and Mill personnel will be trained in the approved SOP prior to processing the Ore or any similar natural monazite sand ore.

All of this will be accomplished pursuant to the Mill's existing radiation program. As a result, no adjustments will be needed to the radiation protection program to process the Ore or similar natural monazite sand ores.

No Adjustments Needed to the Environmental Monitoring Program

The Ore has a uranium content and radioactivity levels comparable to Colorado Plateau ores, and previously-approved alternate feed materials, and contains no additional constituents beyond those associated with other ores or alternate feed materials previously processed at the Mill. The Mill monitors for various isotopes in the U-nat chain under all of its monitoring programs. Also, because Th-nat is found in ores and alternate feed materials processed at the Mill on a routine basis, the Mill currently monitors for Th-232 in its environmental BHV air particulate monitoring stations, and in its environmental soil and vegetation sampling programs. Therefore, Ore and similar natural monazite sand ores will pose no additional hazards during storage, processing or disposal of tailings over and above other ores and alternate feed materials processed on a routine basis at the Mill. As a result, no adjustments will be needed to the environmental monitoring program to process the Ore or similar natural monazite sand ores.

No Adjustments Needed to the Spill and Emergency Response

As discussed above, although the Mill will use some new processing chemicals, all components of those chemicals are already present in the Mill and/or TMS, and the Mill's worker safety and environmental monitoring program addresses those reagents or others of comparable or greater hazard already in use at the Mill. Existing emergency response and spill response procedures are therefore sufficient for management of potential accidents or spills of the Ore or other natural monazite sand ores on the Mill site. As a result, no adjustments will be needed to the spill and emergency response programs to process the Ore or similar natural monazite sand ores.

No Adjustments Needed to the Groundwater Monitoring Program

As discussed in detail under the response to RAI 2, above, Table 4 summarizes the anticipated composition of the tailings solution after processing Ore. The most appreciable change in concentration from processing Ore or similar natural monazite sand ores will result from barium and zirconium. Although to a much lesser degree, noticeable changes in lead, gallium, hafnium, natural thorium and certain REEs are also expected.

In all cases, our conclusion is that lead is already a monitored constituent under the GWDP, and each of the other constituents is well-represented by other constituents which are already analyzed under the GWDP. As a result, there is no need to add any of these constituents as monitoring constituents under the GWDP because of Ore or similar natural monazite sand ore processing.

As a result, no adjustments will be needed to the groundwater monitoring program to process the Ore or similar natural monazite sand ores.

References

Heileson, W. Maholon *Liner/Leachate Compatibility Study* Idaho National Environmental Engineering Laboratory Design File INEEL EDF-ER-278 1/30/2003

MicroShield (Grove 2005).

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 2000. *Sources and Effects of Ionizing Radiation – Volume 1: Sources.* Report to the General Assembly, with Scientific Annexes, United Nations, New York.

US EPA, 1988. Risk Reduction Engineering Laboratory. *Lining of Waste Containment and Other Impoundment Facilities* EPA/600/2-88/052 September 1988

U.S. EPA, 1982. *Final environmental impact statement for remedial action standards for inactive uranium processing sites (40 CFR 192) – Volume 1.* EPA 520/4/82/013-1, October 1982.

CONCLUDING COMMENTS

The Ore is a natural uranium ore that is similar in radionuclide and chemical content to other ores and alternate feed materials that are processed on a routine basis at the Mill. The Ore can be processed at the Mill for the recovery of uranium and REE Concentrate under existing processes and standard operating procedures with minor routine modifications and adjustments typical of the types of modifications and adjustments made by the Mill in its normal processing activities associated with the various ores and feeds it processes on a regular basis.

Because all the constituents in the Ore have either been reported to be, or can be assumed to be, already present in the Mill's TMS or were reported in other conventional ores or licensed alternate feed materials, or in reagents already in use at the Mill, at levels generally comparable to or higher than those reported in the Ore, the resulting tailings will not be significantly different from existing tailings at the facility, and the impacts will not be significantly different from the Ore or similar natural monazite sand ores than from other conventional ores and previously licensed alternate feed materials. Consequently, there will be no incremental public health, safety or environmental impacts over and above existing licensed activities.

Further, the foregoing analysis demonstrates that, were the Mill to receive and process for uranium and an REE Concentrate additional natural monazite sand ores from other sites in the future, with similar characteristics to the Ore, the receipt, processing and disposal of the tailings from 15,000 tons of Ore and such other monazite sands on an ongoing basis would fall well within the environmental envelop for the Mill and would not result in any incremental public health, safety or environmental impacts over and above previously licensed activities. In fact, as demonstrated in this letter, quantities of Ore or similar natural monazite sand ores double that amount (i.e., 30,000 tons per year on an ongoing basis) could be handled easily and safely at the Mill with no incremental public health, safety or environmental impacts over and above previously licensed activities.

As a result, although not expressly evaluated in previous analyses, the process of extracting an REE Concentrate has been environmentally evaluated for the Mill, through the evaluation of similar activities.

The Ore and similar natural monazite sand ores are natural ores. The Mill receives natural ores from conventional mines under its existing SOPs and License and GWDP conditions on a routine basis. There is no reason to treat the Ore and similar natural monazite sand ores any differently. We have demonstrated above that existing Mill SOPs, and License and GWDP conditions are adequate and appropriate for the Ore and similar natural monazite sand ores and that there will be no incremental public health, safety or environmental impacts from receiving and processing Ore and similar natural monazite sand ores over and above existing licensed activities. Consequently, we ask for DWMRC's confirmation with our analysis that the Ore and any similar natural monazite sand ores can be received and processed at the Mill for the recovery of uranium and REE Concentrate under the Mill's existing License and GWDP in any quantities, but at least approximately 5,000 tons per year of Ore and up to 25,000 tons per year of additional similar natural monazite sand ores totaling 30,000 tons per year (or approximately 4% of the Mill's licensed capacity of approximately 720,000 tons per year) on an ongoing basis, without the need for any amendments or approvals.

The Mill would perform a detailed documented evaluation through its SERP similar to the evaluation described in EFRI's June 25, 2020 letter and this letter, before receiving any monazite sand ores other than Ore, to determine that the ores are natural monazite sand ores similar to the Ores and that receipt and processing of such ores for the recovery of uranium and an REE Concentrate would not require any amendments to the Mill's License or GWDP or other approvals, or pose any incremental public health, safety or environmental impacts over and above processing Ore or other previously licensed activities.

Please contact me if you have any questions or require any further information.

Yours very truly,

ENERGY FUELS RESOURCES (USA) INC.
David C. Frydenlund
Chief Financial Officer, General Counsel and Corporate Secretary

cc: Scott Bakken
Garrin Palmer
Logan Shumway
Terry Slade
Kathy Weinel
Doug Chambers, Arcadis
Jo Ann Tischler, Tischler Consulting Services

TABLES

Table 1
Range of Uranium Content in Chemours and Other Monazite Ores

Chemours Sample Name	**U_3O_8 (%)**	**U (%)**
Sample data from email 2019	0.26	0.22
REM1 typical grade	0.184	0.16
REMS2 typical grade	0.182	0.15
REMS3 typical grade	0.181	0.15
REMS4 from additonal mine area	0.189	0.16
REMS5 from additional mine area	0.189	0.16
REMS 6/11 "low grade" sample	0.201	0.17
Average	**0.20**	**0.17**
Minimum	**0.18**	**0.15**
Maximum	**0.26**	**0.22**

Monazite Ore from Africa	**U_3O_8 (%)**	**U (%)**
Typical	**0.12**	**0.10**
Minimum	**0.12**	**0.10**
Maximum	**0.24**	**0.20**

Monazite Ore Queensland, Australia	**U_3O_8 (%)**	**U (%)**
Minimum	**0.12**	**0.1**
Maximum	**0.18**	**0.15**

Notes:

Chemours data is XRF from on site QC lab. One sample was provided to EFRI on December 25, 2019

The REMS sample data was provided on July 6, 2020.

"REM" or "REMS": Rare Earth Mineral Sand.

All Chemours separation products resulted from feeds from Mission Mine.

Other Chemours mines are within the same geologic formation.

Africa XRF data provided to EFRI by the mine owner.

Queensland, Australia data obtained from World Nuclear Association 2019.

Table 2
Chemours Mineral Assay Data

Sample name	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	P_2O_5	SO_3	SrO	ZrO_2	BaO	NiO	CuO	P
	Si	Ti	Al	Fe	Mg	Ca	K	P	S	Sr	Zr	Ba	Ni	Cu	l
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(
REM1 met 2116	3.4	0.220	0.470	0.154	-0.013	0.694	0.002	20.4	0.101	0.033	5.5	0.513	0.072	0.015	0.
REMS2 met 2117	3.8	0.240	0.540	0.157	0.010	0.670	0.008	20.1	0.082	0.036	6.4	0.489	0.062	0.013	0.
REMS3 met 2118	4.0	0.340	0.650	0.253	0.001	0.674	0.004	19.3	0.090	0.033	6.6	0.441	0.068	0.016	0.
REMS4 met 2119	3.1	0.180	0.410	0.169	-0.006	0.687	0.005	20.3	0.100	0.033	5.1	0.456	0.075	0.019	0.
REMS5 met 2120	3.9	0.560	0.440	0.297	0.021	0.657	0.005	19.6	0.103	0.040	6.7	0.503	0.067	0.016	0.
REMS 6/11 met 2121	4.9	1.410	0.530	0.634	0.038	0.662	0.004	19.4	0.089	0.041	8.4	0.512	0.081	0.016	0.
December 25, 2019 sample	5.2							18.3			9.2				
Mineral Average	4.0	0.492	0.507	0.277	0.009	0.674	0.005	19.6	0.094	0.036	6.9	0.486	0.071	0.016	0.
Atomic Wt Element	28.09	47.87	26.98	55.85	24.31	40.08	39.10	30.97	32.06	87.62	91.22	137.33	58.69	63.54	20
Atomic Wt Oxygen	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	1
Ratio element/mineral	0.47	0.60	0.53	0.70	0.60	0.71	0.83	0.44	0.40	0.85	0.74	0.90	0.79	0.80	0
Element Ave %	1.89	0.29	0.27	0.19	0.01	0.48	0.004	8.56	0.04	0.03	5.07	0.43	0.06	0.01	0
Element Avg mg/kg	18,899	2,947	2,681	1,940	51	4,817	38.7	85,633	377.1	304	50,721	4,350	557	126	l

NOTES:

The elemental metal to mineral mass ratio was calculated separately for each mineral, based on the stoichiometric ratio of metal or cation atoms to oxygen atoms.
Chemours data was provided for one sample on December 25, 2019 and the remainder on July 6, 2020.

Some minerals were not specified in the December 2019 sample.
Scandium was not identifed in July 6, 2020 samples, but was present in the December
Some data was reported as % and some as ppm (mg/kg) in the July 6, 2020 samples.
Values have been converted for calculations.
Met numbers (e.g. "21XX") are sample identification numbers, not years.

Table 2
Chemours Mineral Assay Data

Sample name	Er2O3	Eu2O3	Ga2O	Gd2O3	Ho2O3	La2O3	Nd2O3	Pr6O11	Sm2O3	Tb4O7	Tm2O3	Yb2O3	Y2O3
	Er	Eu	Ga	Gd	Ho	La	Nd	Pr	Sm	Tb	Tm	Yb	Y
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
REM1 met 2116	1,705	2,846	2	15,650	945	105,144	101,981	26,593	17,642	2,711	262	1,741	30,191
REMS2 met 2117	1,520	2,851	<DL	15,271	841	104,573	100,683	26,247	17,387	2,678	235	1,575	27,673
REMS3 met 2118	1,494	2,801	<DL	14,568	820	99,881	95,880	25,036	16,549	2,527	222	1,597	27,971
REMS4 met 2119	1,627	2,882	<DL	16,039	876	104,801	103,085	26,793	18,221	2,785	237	1,599	29,627
REMS5 met 2120	1,574	2,832	<DL	15,214	918	99,652	97,459	25,253	17,175	2,664	242	1,700	29,417
REMS 6/11 met 2121	2,000	2,672	6	14,945	991	92,807	91,844	23,996	16,459	2,591	276	2,111	33,075
December 25, 2019 sample	1,300	1,400		11,900	700	10,580	92,400	26,900	16,900	1,700		1,000	21,200
Mineral Average	1,603	2,612	4.2	14,798	870	88,205	97,619	25,831	17,190	2,522	246	1,617	28,450
Atomic Wt Element	167.26	151.96	69.72	157.25	164.93	138.91	144.24	140.91	150.36	158.93	168.93	173.05	88.91
Atomic Wt Oxygen	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Ratio element/mineral	0.87	0.86	0.90	0.87	0.87	0.85	0.86	0.83	0.86	0.85	0.88	0.88	0.79
Element Ave %													
Element Avg mg/kg	1,401.6	2,256	3.7	12,839	759	75,211	83,693	21,380	14,824	2,145	215	1,420	22,403

NOTES:

The elemental metal to mineral mass ratio was calculated separately for each mineral, based on the stoichiometric ratio of metal or cation atoms to oxygen atoms.

Chemours data was provided for one sample on December 25, 2019 and the remainder on July 6, 2020.

Some minerals were not specified in the December 2019 sample.
Scandium was not identifed in July 6, 2020 samples, but was present in the
Some data was reported as % and some as ppm (mg/kg) in the July 6, 2020 samples. Values have been converted for calculations.
Met numbers (e.g. "21XX") are sample identification numbers, not years.

Table 3 Rare Earth Elements in Arizona Strip and Four Corners Area Uranium Ores

Component	A Estimated Conc.Range in AZ/CO Ore (mg/kg or ppm)[1]	B Estimated midpoint Conc. in AZ/CO Ore (mg/kg or ppm)[1]	C Estimated Mass in Tailings Cell 3 from 100% AZ/CO Ore (tons)[2]	D Mass in Tailings Cell 3 from 83% AZ/CO Ore[3]	E Concentration in Mill Tailings (Cell 4A) (mg/kg or ppm)[4]
Cerium (Ce)	12.9-350	182	494.6	410.5	150.91
Dysprosium (Dy)	0-70	35	95.4	79.2	29.10
Erbium (Er)	0-66.2	33.0	89.9	74.6	27.44
Europium (Eu)	0.8-26	13.4	36.5	30.3	11.14
Gadolinium (Gd)	1.8-98	50.0	136.1	113.0	41.53
Holmium (Ho)	0-29.8	15.0	40.9	33.9	12.47
Lanthanum (La)	18-35	27	72.2	59.9	22.03
Lutetium (Lu)	0.25-4.81	2.5	6.9	5.7	2.10
Neodymium (Nd)	2.5-500	251	684.7	568.3	208.91
Praseodymium (Pr)	0-87.9	44	119.8	99.4	36.54
Promethium (Pm)	0	0	0.0	0.0	0.00
Samarium (Sm)	0.5-140	70	191.4	158.9	58.41
Scandium (Sc)	2.5-8	5.3	14.3	11.9	4.37
Terbium (Tb)	0.3-28.2	14.3	38.8	32.2	11.85
Thulium (Tm)	0.11-7.98	4.0	11.0	9.1	3.36
Ytterbium (Yb)	0.2-39.8	20.0	54.5	45.2	16.63
Yttrium (Y)	0-419	210	570.9	473.8	174.19
Total REEs			2,658	2,206.1	**811**

Notes to Table:

1. AZ/CO Ore concentrations were taken from

   Van Gosen, B.S. 2020 *Geochemical and Xray Diffraction Analysis of Drilling Core Samples from the Canyon Uranium Deposit - A solution Collapse Breccia Pipe*,

   USGS *Assay Data from Hack-Pigeon Mining Area Az Strip*

   Della Valle, R. S. & Brookins, D.G., 1984 *Samples from the Grants Mineral Belt, New Mexico*, and *Trace Element Distributions in Sedimentary-Type Uranium Deposits*

   These values represent two ores from the AZ strip and one from the vicinity of the 4 corners Colorado Plateau.

2. Estimated mass of each REE in tailings is calculated by multiplying concentraton by 2,725,000 dry tons of tailings in Cell 3.

3. Total alternate feed materials prior to 2012 are 471,000 tons or 17% of the filled mass of Cell 3.

   Only one or two Alternate Feed Materials had appreciable levels of REEs. As a result, alternate feed material contribution to REEs in tailings Cell 3 is small enough to be neglected in calculations.

   We therefore assume that 83% of the mass of Cell 3 is comprised of AZ/CO ores, with the average REE concentrations in ore set out in Column B. Asssuming that the ore tailings are 83% of the total tailings yields the REE masses in Column D and the REE concentrations in Column E.

4. Cell 4A was placed in operation in approximately 2012 and contains approximately 750,000 dry tons of tailings solids.

   Consistent with Cell 3, we have assumed that 83% of the tailings solids in Cell 4A are from AZ/CO ores, having the REE concentration set out in Column C. These concentrations were used with the mass of 750,000 dry tons of Cell 4A tailings in the calculations in Table 4.

Table 4

Comparison of Chemours Ore to Tailings in a Full Cell 4A

Component	A Estimated Average Conc. in Ore (mg/kg or ppm)	B Estimated Mass in Ore (tons)	C Conc. Range in Mill Tailings before Processing Ore (mg/L or *ppm*)	D Estimated Average Conc. in Mill Tailings before Processing Ore (mg/L or ppm)	E Estimated Mass in Mill Tailings before Processing Ore (tons)	F Mass in Mill Tailings after Ore Processing (tons)	G Conc. in Mill Tailings after Ore Processing (ppm)	H Difference between Column G & D (Incremental Increase in Mill Tailings Conc. after Ore Processing) (ppm)	I Increase in Mill Tailings Conc. after Ore Processing (%)	J Conc. in Ores and Other Alternate Feed Materials (mg/kg or ppm)
P as phosphate	85,633	12,845.0	Not analyzed in Mill tailings							610,000 **
Aluminum (Al)	2,681	402.2	1,510	1,510	3,020	3,422.2	1,592	81.7	5.4	2,000-160,000
Barium (Ba)	4,350	652.5	0.10	0.10	0	652.7	304	303.5	303,481	21-36,200
Calcium (Ca)	4,817	722.6	445-707	584	1,168	1,890.6	879	295.3	50.6	up to 217,000
Copper (Cu)	127	19.0	99.2-683	573	1,146	1,165.0	542	-31.2	-5.4	8-296,000
Gallium (Ga)	13,258	1,988.7	Not analyzed in Mill tailings							
Hafnium (Hf)	1,821	273.2	Not analyzed in Mill tailings							
Iron (Fe)	1,940	291.0	2,280-5,320	3,703	7,406	7,697.0	3,580	-123.0	-3.3	up to 164,000
Lead (Pb)	1,092	163.8	5.27-16.4	14	28	191.8	89	75.2	537.2	9-262,400
Magnesium (Mg)	51	7.7	2,230-7,030	4,323	8,646	8,653.7	4,025	-298.0	-6.9	1,020-43,400
Manganese (Mn)	1,546	231.9	112-307	217	434	665.9	310	92.7	42.7	172-3,070
Nickel (Ni)	557	83.6	17.1-71.9	59	118	201.6	94	34.74	58.89	7-450,000
Potassium (K)	39	5.8	558-2,020	1,230	2,460	2,465.8	1,147	-83.1	-6.8	17-7,740
Strontium (Sr)	304	45.6	Not analyzed in Mill tailings							1,210
Sulfide (S)	377	56.6	Not analyzed in Mill tailings							9,846
Thorium-nat (Th-nat)	31,750	4,762.5	240.4	240.4	480.8	5,243.3	2,439	2198	914	22,000
Titanium (Ti)	2,947.00	442.1	Not analyzed in Mill tailings							38,800
Zinc (Zn)	612	91.8	169-406	292	584	675.8	314	22.3	7.6	8-14,500
Zirconium (Zr)	50,721	7,608.2	2.53	2.53	5	7,613.2	3,541	3538.5	139,862	51,000
Cerium (Ce)	199,516	149.6	Not Analyzed	150.9	302	451.4	210	59.1	39.1	31,600
Dysprosium (Dy)	5,764	4.3	Not Analyzed	29.1	58	62.5	29	0.0	-0.1	9,100
Erbium (Er)	1,402	1.1	Not Analyzed	27.4	55	55.9	26	-1.4	-5.2	22.00
Europium (Eu)	2,256	1.7	Not Analyzed	11.1	22	24.0	11	0.0	0.1	26.00
Gadolinium (Gd)	12,839	9.6	Not Analyzed	41.5	83	92.7	43	1.6	3.8	20,000
Holmium (Ho)	759	0.6	Not Analyzed	12.5	25	25.5	12	-0.6	-4.9	11.00
Lanthanum (La)	75,211	56.4	Not Analyzed	22.0	44	100.5	47	24.7	112.1	160,000
Lutetium (Lu)	0	0.0	Not Analyzed	2.1	4	4.2	2	-0.1	-7.0	No feeds analyzed
Neodymium (Nd)	83,693	62.8	Not Analyzed	209	418	480.6	224	14.6	7.0	151,100
Praseodymium (Pr)	21,233	15.9	Not Analyzed	36.5	73	89.0	41	4.9	13.3	39,500
Samarium (Sm)	14,824	11.1	Not Analyzed	58.4	117	127.9	60	1.1	1.9	5,200
Scandium (Sc)	65	0.0	Not Analyzed	4.4	9	8.8	4	-0.3	-6.5	7.00
Terbium (Tb)	2,145	1.6	Not Analyzed	11.9	24	25.3	12	-0.1	-0.7	15.00
Thulium (Tm)	215	0.2	Not Analyzed	3.4	7	6.9	3	-0.2	-4.7	2.40
Ytterbium (Yb)	1,420	1.1	Not Analyzed	16.6	33	34.3	16	-0.7	-4.0	14.00
Yttrium (Y)	22,403	16.8	Not Analyzed	174.2	348	365.2	170	-4.3	-2.5	419

Notes to Table:

1. The concentrations in the Chemours Ore are from 2019 and 2020 Chemours data.
2. Estimated mass in the Ore is calculated by multiplying column A by an assumed 150,000 dry tons of Ore for non REEs and 15,000 tons for REEs. This assumes processing Ore for 9 years at 15,000 tons/year and disposing 1 year of unprocessed receipts directly in tailings.
3. Cell 4A Mill tailings range and average concentrations were taken from Mill tailings samples to date, as summarized in the Annual Tailings Characterization Report except for Al, Ba, Sn and Zr. These metals were analyzed by AWAL Laboratories in additional samples collected in 2019.
4. Cell 4A at capacity would contain approximately 2,150,000 dry tons tailings: 150,000 tons from Ore and 2,000,000 tons from other ores plus alternate feed materials.
5. Mass of constituent in Mill tailings after processing Ore is calculated by adding columns B and E.
6. The concentration in Mill tailings after processing Ore is calculated by dividing column F by 2,150,000, which is the final volume of tailings in Cell 4A of 150,000 dry tons of Ore in in ten years (one year directly disposed without processing), plus 2,000,000 tons of tailings from other feeds.
7. The increase in Mill tailings concentration after processing Ore (ppm) shows the increase (decrease) in concentration of each constituent in the Mill's tailings, stated in ppm of the total mass of tailings in Cell 4A, which is calculated as the difference between column G and column D.
8. *The increase in Mill tailings concentration after processing Ore is the ratio of Column D to Column H expressed in %*
9. The concentration in other alternate feeds represents some selected concentrations for constituents found in characterization data for other ores and alternate feed materials licensed for processing at the Mill, for comparison purposes.
10. Sulfate was not inlcuded. Tailings solutions are overwhelmingly composed of residual sulfate from the Mill process.
11. Sources of data for selected elements in other feeds is provided in Table 6.
12. Scandium was taken from the single value in the December 2019 data table from Chemours. It is not present in the July 2020 data.
13. REEs in tailings were approximated from maximum values in Cell 3 which received 83% ores, 17% alternate feed materials. It is assumed Cell 4A will receive tailings from a comparable mix of feeds.
14. Historically, natural thorium was not measured on a mass concentration basis in tailings solutions, and activity concentrations of three thorium isotopes, Th-228, Th-230 and Th-232, have only been measured since 2015. Thorium-nat was estimated from 0.002% Th-nat in natural ores per NRCP 1988 Report, 2.2% Th-nat in SFC material, and excluding Th from other alternate feed materials.

▨ Names of Rare Earth Elements (REEs) are shaded. REE concentrations in tailings were calculated in Table 3.

Table 5 Comparison of WR Grace Alternate feed Material to Cell 3 Full Cell

Component	A Estimated Average WRG (mg/kg or ppm)	B Estimated Mass in WRG (tons)	C Conc. Range in Mill Tailings before Processing WRG (mg/L or *ppm*)	D Estimated Average Conc. in Mill Tailings before Processing WRG (mg/L or ppm)	E Estimated Mass in Mill Tailings before Processing WRG (tons)	F Mass in Mill Tailings after Processing WRG (tons)	G Conc. in Mill Tailings after Processing WRG (ppm)	Difference between Column G & D (Incremental Increase in Mill Tailings Conc. after Processing WRG) (ppm)	I Increase in Mill Tailings Conc. after Processing WRG (%)	J Conc. in Other Ores and Alternate Feed Materials (mg/kg or ppm)
Thorium 232 (Th-232)	72,730	14,764	9.05	9.05	22.8	14,787	5,426	5417	59,861	22,000
Thorium 230 (Th230)	0.105	0.021	0.038	0.038	0.1	0.1	0.043	0.005	13	3.9
	pCi/g		pCi/g	pCi/g			pCi/g	pCi/g	%	pCi/g
Thorium 230 (Th230)	2,000		726	726			821	94.6	13	2,300,000

Notes to Table:

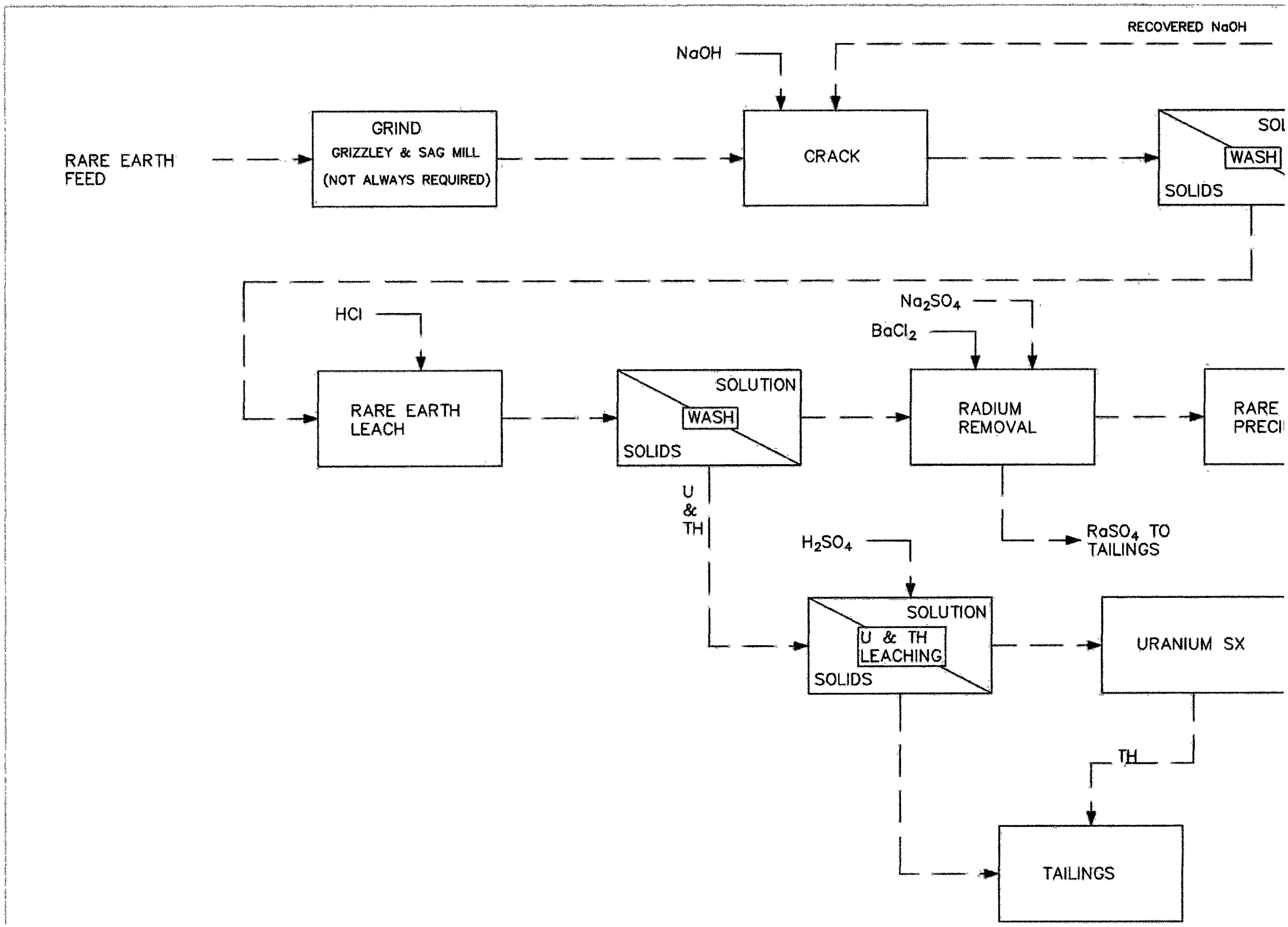
1. The concentration in WR Grace ("WRG") alternate feed material is from 2000 AR data.
2. Estimated mass in the WR Grace material is calculated by multiplying column A by an assumed 203,000 tons of WR Grace material..
3. Cell 3 when full contains approximately 2,522,000 dry tons tailings apart from WR Grace material: 2,093,260 tons from natural ores and 428,740 tons from alternate feed materials.
4. Mass of constituent in Mill tailings after processing WR Grace is calculated by adding columns B and E.
5. The concentration in Mill tailings after processing WR Grace is calculated by dividing column F by 2,725,000, which is the 2,522,000 tons of tailings from ores and other alternate feeds plus 203,000 tons of tailings from WR Grace material.
6. The increase in Mill tailings concentration after processing Ore (ppm) shows the increase (decrease) in concentration of each constituent in the Mill's tailings, stated in ppm of the total mass of tailings in Cell 4A, which is calculated as the difference between column G and column D.
7. The increase in Mill tailings concentration after processing WR Grace material is the ratio of Column D to Column H expressed in %
8. The concentration in other alternate feeds represents some selected concentrations for thorium isotopes found in characterization data for other ores and alternate feed materials licensed for processing at the Mill, for comparison purposes.
9. Sources of data for thorium isotopes in other feeds is provided in Table 6.
10. Concentration in pCi/g after processing WR Grace is the weighted average of (2,000 x 203,000) + (726 x 2,522,000) divided by full capacity of Cell 3 or (203,000 + 2,522,000)

Table 6: Elements Present in Other Previously Processed Feeds

Chemical	Value in Tailings Table 4 for Concentration in Other Feeds	Supporting or Additional Information	Source
Barium	36,244 mg/kg	3.62 % in Molycorp Mt. Pass drummed alternate feed material	Molycorp characterization data in amendment request December 2000.
Cerium	31,600 mg/kg	---	FMRI Amendment Request March 2005
Dysprosium	9,100 mg/kg	---	Heritage RMPR July 2000
Gadolinium	20,000 mg/kg	---	Heritage RMPR July 2000
Hafnium	5,720 mg/kg	---	FMRI Amendment Request March 2005
Lanthanum	160,000 mg/kg	---	Heritage RMPR July 2000
Lanthanides	217,200 mg/kg	---	Molycorp letter 1995
Lead	262,410 mg/kg		Molycorp additional amendment request 2000
Neodymium	151,000 mg/kg	---	Heritage RMPR July 2000
Niobium	27,300 mg/kg	---	FMRI Amendment Request March 2005
Phosphorus as Phosphate	610,000 mg/kg	Cameco Calcined alternate feed, 8 to 20% as PO_4^{-3} (2.6 to 6.5% or 26,000 to 65,000 mg/kg)	SDS for Cameco Calcined Product
Praseodymium	39,500 mg/kg	---	Heritage RMPR July 2000
Samarium	5,200 mg/kg	---	Cited in USM ore application summary tables for previously approved feeds
Scandium	4,170 mg/kg	---	FMRI Amendment Request March 2005
Strontium	1,120 mg/kg	---	SFC RMPR 2011
Sulfide	Up to 9,846 mg/kg	Sulfur in Molycorp material is in sulfide and sulfate form	Molycorp amendment request 1995
Tantalum	51,000 mg/kg	---	SFC RMPR and Amendment Request 2011
Thorium total	0.0058 to 0.0270% med. 0.0180%	500 to 35,000 pCi/g weighted avg. 15,000	Heritage RMPR July 2000
Thorium total	14,700 mg/kg		FMRI Amendment Request March 2005
Thorium total	2.2% 22,000 mg/kg		SFC Amendment Request 2011
Thorium-228		2,700 pCi/g	Cameco calcined RMPRs
Thorium-228		up to 1,110 weighted avg. 699	SFC RMPR 2011
Thorium-230	121 mg/kg	2,300,000 pCi/g	Cotter Concentrate letter
Thorium-230	Up to 3.9 mg/kg Weighted avg. 2.9 mg/kg	up to 74,400 pCi/g weighted avg. 55,685 pCi/g	SFC RMPR 2011
Thorium-232	54,545 mg/kg	6,000 pCi/g	SFC RMPR 2011
Thorium-232		up to 4,990 pCi/g	Heritage RMPR July 2000
Titanium	38,800 mg/kg	---	March 2005
Yttrium	49,000 mg/kg	---	Heritage RMPR July 2000
Zirconium	51,000 mg/kg	---	FMRI Amendment Request March 2005

Acronyms
FMRI: Fansteel Metals Resources, Inc.
SDS: Safety Data Sheet
RMPR: Radioactive Material Profile Record
SFC: Sequoyah Fuels Corporation
USM ore: Uranium Source Material ore

FIGURES


RECOVERED NaOH
NaOH
RARE EARTH FEED
GRIND
GRIZZLEY & SAG MILL
(NOT ALWAYS REQUIRED)
CRACK
SOL
WASH
SOLIDS
HCl
RARE EARTH LEACH
SOLUTION
WASH
SOLIDS
Na_2SO_4
$BaCl_2$
RADIUM REMOVAL
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PRECI
U & TH
$RaSO_4$ TO TAILINGS
H_2SO_4
SOLUTION
U & TH LEACHING
SOLIDS
URANIUM SX
TH
TAILINGS

Alyssa Stringham <astringham@utah.gov>

Fwd: EFRI Responses to Request for Additional Information

1 message

Phillip Goble <pgoble@utah.gov> Wed, Sep 9, 2020 at 12:15 PM
To: Alyssa Stringham <astringham@utah.gov>

Alyssa,

Please print out the attached document and give it to the front desk for scanning.

Thanks,

Phil

---------- Forwarded message ---------
From: **Kathy Weinel** <KWeinel@energyfuels.com>
Date: Wed, Sep 9, 2020 at 12:13 PM
Subject: EFRI Responses to Request for Additional Information
To: tyhoward@utah.gov <tyhoward@utah.gov>
Cc: Phillip Goble <pgoble@utah.gov>, rmjohnson@utah.gov <rmjohnson@utah.gov>, Thomas Rushing <trushing@utah.gov>, Scott Bakken <SBakken@energyfuels.com>, Garrin Palmer <GPalmer@energyfuels.com>, Logan Shumway <LoShumway@energyfuels.com>, Terry Slade <TSlade@energyfuels.com>, Doug Chambers - SENES (Doug.Chambers@arcadis.com) <Doug.Chambers@arcadis.com>, Ho, Arnon (Arnon.Ho@arcadis.com) <Arnon.Ho@arcadis.com>, japmst55@gmail.com <japmst55@gmail.com>

Mr. Howard,

Attached please find the Energy Fuels Resources (USA) Inc. ("**EFRI's**") responses to the Division of Waste Management and Radiation Control's ("**DWMRC's**") July 21, 2020 Request for Additional Information ("**RAI**") regarding EFRI's, June 25, 2020 letter regarding receipt and processing of ores from Chemours at the Mill (the "**Ore**") for the recovery of uranium and a rare earth element ("**REE**") concentrate ("**REE Concentrate**").

A hard copy has been sent for your convenience.

Please contact me if you have any questions on this transmittal.

Yours Truly,

Kathy Weinel

Energy Fuels Resources (USA) Inc.

Kathy Weinel
Quality Assurance Manager

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Lakewood, CO 80228

http://www.energyfuels.com

Chemours RAI Responses 09.09.20.pdf
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