Memorandum

To: Steve Tarleton, Colorado Department of Public Health and Environment

cc: Hilary White, Sheep Mountain Alliance; and
Warren Smith, Colorado Department of Public Health and Environment

From: James Holmes, MS; Ann Maest, PhD; Constance Travers, MS; and
Cameron Wobus, PhD, Stratus Consulting Inc.

Date: 12/14/2010

Subject: Revised comments on Energy Fuels' proposed Piñon Ridge uranium mill

On September 28, 2010, we provided the Colorado Department of Public Health and Environment (CDPHE) with our initial comments on the proposed Piñon Ridge uranium mill near Naturita, Colorado. In this memorandum, we summarize our initial comments and discuss whether subsequent documents released by Energy Fuels addressed our comments. Sheep Mountain Alliance retained Stratus Consulting to provide the comments in this memorandum.

The mill proponent, Energy Fuels, has released several additional documents since early June, many of which address questions and comments that CDPHE provided in four separate requests for information (RFIs). Most of the additional information addresses geotechnical and engineering design questions. Many broader questions related to water supply, waste management, adaptive management, and contingencies remain unclear. However, some responses to RFIs address specific issues that we previously identified, and we have attempted to integrate those responses into our analysis herein.

As we did in the previous memorandum, we first review the water supply plan, focusing mainly on uncertainties in the estimate of available groundwater underlying the site. Section 2 reviews the potential toxicity of the liquid wastes that the mill would generate. Section 3 discusses waste containment and contaminant pathways that could occur if the proposed containment fails. Section 4 reviews the potential cost of uranium mill remediation. Finally, Section 5 presents the qualifications of the authors of this memorandum.

1. Water Supply

According to the hydrogeologic report (Golder Associates, 2009), the mill will require 144 gallons per minute (gpm) to sustain operations, including 3 gpm of potable water and 141 gpm of non-potable water. The only water sources available in the immediate area are the Chinle-Moenkopi aquifer underlying the site, and the San Miguel River near Naturita. Golder Associates has stated, "the on-site aquifer is estimated to be capable of delivering 100 to 175 gpm sustainably" (Golder Associates, 2009, p. 31).

In our previous comments, we reviewed the water supply evaluation (Golder Associates, 2008) and the hydrogeologic report (Golder Associates, 2009) and concluded that the above estimate of aquifer production is highly optimistic. There is little recharge to the Chinle-Moenkopi aquifer, and the aquifer is likely bounded by a salt dome to the northeast and faults to the southwest, limiting groundwater inflow from outside of the area proposed for installation of water supply wells. In response to an RFI from CDPHE, Golder Associates (2010) suggested that the vertical pathways are highly anisotropic, with interbedded clay and shale layers, resulting in a low vertical hydraulic conductivity. This supports the assumption that little or no recharge will occur. We continue to believe that most of the water supply from this aquifer should be assumed to be already stored in the aquifer rather than a “sustainable” source from influent precipitation.

Golder Associates (2008) estimated that the aquifer has a low storativity[1] of 0.01, indicating little available water, based on data from the most productive wells that they tested. Fractures within the matrix provide additional water, but the long-term sustainability of accessing water in fractures is uncertain. The optimistic estimates of aquifer production are based on pumping tests from three wells that are all in a cluster (Figure 1), likely accessing the same water. Extrapolating these results to a broader area of the aquifer may be problematic, as evidence suggests that other wells are not nearly as productive. In its review of other wells in the vicinity that are completed in the Chinle-Moenkopi aquifer, Golder Associates (2009) found five operable wells that produce 8–20 gpm, and three wells that were inoperable or intermittent because of a lack of recharge. Given the production of existing wells, the assertion that five production wells can produce up to 175 gpm (an average of 35 gpm per well) for the next 40 years is questionable.

The upper end of the sustainable pumping rate estimate (175 gpm) provided by Golder Associates (2009) assumes generous recharge from Davis Mesa (recharging an aquifer 300–500 ft deep), and it assumes only one boundary restricting aquifer flow. However, as mentioned previously, the aquifer is likely bounded to the northeast by a salt dome and to the southwest by faults in the mesa (Figure 1). When including both of these two boundaries in their calculations, Golder Associates (2008) estimates that only 64 gpm can be sustainably pumped from the aquifer, where sustainability is defined as a five-year period. They did not provide an analysis of the sustainability of aquifer pumping during the subsequent 35 years that the mill is expected to be operating.

1. Storativity is the amount of water released from storage per unit decline in hydraulic head per unit area of the aquifer. In practical terms, lower storativity generally means less available water per unit volume of aquifer.

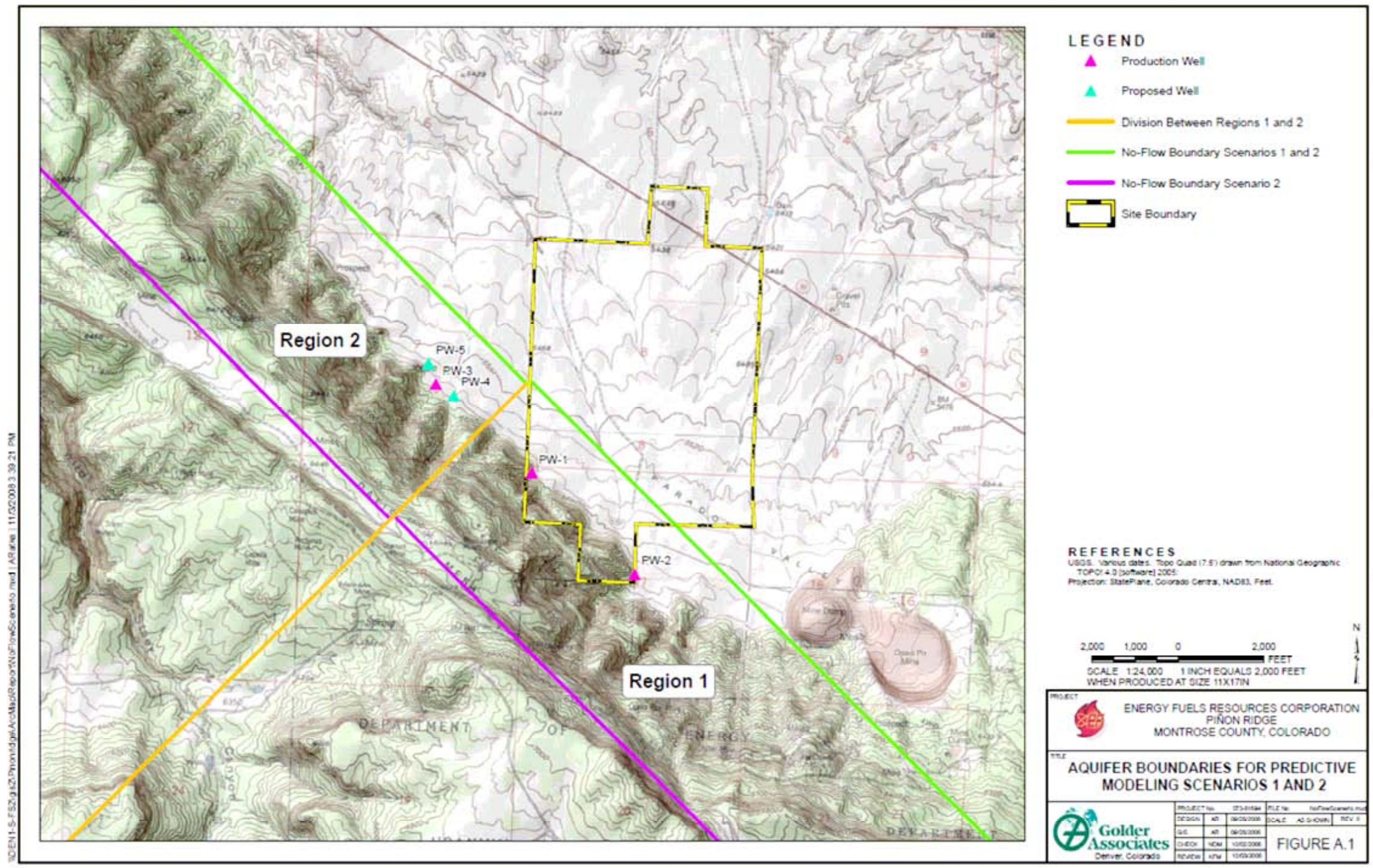

Figure 1. Aquifer boundaries near the Piñon Ridge mill. The aquifer extent is bounded on two sides (purple and green lines). Productivity estimates are based primarily on PW-3, PW-4, and PW-5, which are all clustered in the same area.

Source: Golder Associates, 2009, Figure A.1.

With the uncertainty in their data, optimistic assumptions, and no further analysis of water supplies in their recent documents, we do not believe that Energy Fuels and their contractor, Golder Associates, have adequately addressed questions of water supply over the proposed 40-year mill life. It is not unreasonable to assume that this aquifer will provide only a fraction of the non-potable water requirements for the mill. If this is the case, more water will need to be obtained than the proposed 104-gpm contingency water supply from the San Miguel River at Naturita.

As we stated in our previous comments, we recommend that Energy Fuels revise their water supply plan to explore other alternatives if the aquifer is unproductive. This should include a more detailed analysis of the water that Naturita would supply, such as the feasibility of using this water during a drought, particularly if there are more senior water rights holders downstream of Naturita. It should also include a plan for obtaining an additional 40 gpm from another source if the Chinle-Moenkopi wells go dry, and an analysis of the effects of constant truck traffic if the mill uses primarily San Miguel River water. Finally, Energy Fuels should include a temporary closure or other contingency plan in the event that they are unable to obtain the 144 gpm required for operations, including a plan for maintaining water levels in tailings impoundments and evaporation ponds.

2. Toxicity of Liquid Wastes

In our previous comments, we examined the concentrations of contaminants in raffinate. We share CDPHE's concern about the chemical composition and contaminant concentrations of barren raffinate to be sent to tailings cells and evaporation ponds, and we agree that "ideally, the waste discharged to the tails should be as environmentally innocuous as possible" (CDPHE, 2010a, p. 10).

To review, Dwyer (2008) presented an ecological screening of raffinate process water, in which barren raffinate water was created from bench-scale processing of two local uranium ores (Pandora and Pack Rat). The raffinate water from both of these ores was highly acidic and contained extremely high concentrations of all metals and metalloids listed in Table 1, most notably arsenic, cadmium, lead, selenium, uranium, vanadium, and zinc. Most of the metal concentrations exceeded water quality standards by orders of magnitude, indicating that the raffinate would be highly toxic to exposed humans and aquatic life. In addition, concentrations of contaminants exceed water quality standards for use in agriculture and livestock watering (see, e.g., Wyoming Department of Environmental Quality, 2010) by orders of magnitude. Should any of the proposed waste containment and wildlife exclosure methods fail (see subsequent section), the potential exists for severe degradation of natural resources, even if the mine waters are diluted by mixing with clean groundwater or surface water after release.

Table 1. Contaminant concentrations (mg/L, unless otherwise noted) in barren raffinate for the Piñon Ridge mill, using feedstock from two local ores

Contaminant	Pandora ore raffinate	Pack Rat ore raffinate	Drinking water standard[a]	Acute aquatic life criterion[b]
pH (SU)	1.8	1.8	6.5–8.5	
Arsenic	11.5	58.9	0.01	0.34
Beryllium	0.2	0.28	0.004	
Cadmium	1.19	3.67	0.005	0.002
Chromium	3.27	2.56	0.1	0.570/0.016[c]
Copper	3.96	5.62	1.3 (TT)	0.013
Lead	3.07	0.52	0.015	0.065
Nickel	7.96	8.83	0.1	0.47
Selenium	5.49	14	0.05	0.186/0.013[d]
Silver	0.34	0.53	0.1	0.0032
Uranium	366	369	0.03	–
Vanadium	97.9	195	–	–
Zinc	48.4	40.6	2	0.12

TT = treatment technique or action level.

a. U.S. EPA (2010a) Maximum Contaminant Level; nickel, silver, zinc = lifetime health advisory; pH = secondary standard.

b. U.S. EPA (2010b) surface water quality criteria (assumes 100 mg/L hardness for hardness-dependent criteria).

c. Chromium III/VI.

d. Selenium IV/VI.

The concentrations of many contaminants decreased substantially when the simulated raffinate was neutralized, raising the pH from 1.8 to 7.5 (Dwyer, 2008). However, in response to CDPHE’s request that raffinate be as innocuous as possible, Energy Fuels dismissed raffinate neutralization, stating, “neutralization of the acidic raffinate process waters before discharge to surface impoundments would not reduce the metal concentrations in the solution to non-toxic levels for wildlife” (SENES Consultants, 2010, p. 10). Even if the neutralization step did not lower metals concentrations below toxicity thresholds, it would make the raffinate substantially less toxic. Given the possibility that one of their containment or exclosure measures will fail (see subsequent section), we believe interim steps should be required to reduce the toxicity of the liquid waste.

Finally, we note that in the revised operating procedures for tailings disposal (Energy Fuels Resources, 2010c, Exhibit 4), Energy Fuels states that tailings of 50% solids and 50% water with a pH of 3 will be mixed with vanadium raffinate to produce a slurry that is 27% solids with a pH of 3.4. Clearly, the tailings slurry will be highly acidic and contain high concentrations of toxic metals. While we agree that “bird balls” are a good solution for keeping waterfowl off the ponded areas, we share CDPHE's concern that Energy Fuels has not adequately addressed the need to prevent waterfowl exposure to tailings beaches. In our experience at other mill sites in arid and semi-arid areas, waterfowl do not avoid tailings beaches, even though "these areas will not support a food source for the birds and the noise and movements associated with mill activity may also act as a deterrent" (Energy Fuels Resources, 2010d, p. 7). The Energy Fuels proposal to monitor mortality and if necessary build a clean water supply nearby and implement hazing measures at the tailings is one step toward a mitigation plan. These sorts of mitigation measures should be included in the plan design and budget. Further, hazing may not be a good solution without frequent oversight.

3. Waste Containment

As we stressed in our initial comments, it is imperative that Energy Fuels contain their liquid wastes and prevent biota from being exposed. We commend CDPHE for sharing this concern: "The Division is very concerned about possible spills and releases to the soil inside of process buildings/secondary containment areas but also exterior to those areas due to leaks and pipeline failures of wastes, and process fluids, and fuels/chemicals" (CDPHE, 2010a, p. 1).

We note that Energy Fuels has proposed double liners under evaporation and tailings impoundments, netting around the evaporation ponds, and bird balls on tailings impoundments. While these measures are certainly good, experience from other locations indicates that they could fail, and we do not believe the appropriate contingency measures have been assessed. In particular, Energy Fuels has not included any additional containment and exclosure steps to prevent harm to natural resources should the initial lines of defense fail. We address these issues in additional detail below.

3.1 Pipe Failure: Secondary Containment

CDPHE noted that buried double-wall piping might be more protective than single-walled piping with trenches as secondary containment (CDPHE, 2010c). As discussed in the previous section, the product that those pipes will be carrying is highly toxic to wildlife, justifying extensive and potentially redundant containment measures. We suggest that CDPHE *require* double-wall piping, and secondly, we suggest that perhaps the potential impacts of pipe failure justify both double-wall piping and lined trenches, despite the added cost.

3.2 Bird Netting

The proposed exclosure technique for the evaporation ponds is emplacement of bird netting. Placing bird nets over 40 acres of evaporation ponds in windy, semi-arid, high ultraviolet (UV) light conditions may be problematic. For example, one proponent of a competing bird deterrent system states that netting over a 40-acre pond costs $1.8 to $2.4 million, requires 25% to 35% of that installation cost per year to maintain the net (i.e., $450,000 to $840,000 per year), and requires that the net be replaced every four to five years because of UV degradation (BirdAvert, 2009). Nets exposed to snow loads and high winds, both of which are likely at the Piñon Ridge mill site, are prone to failure (BirdAvert, 2009).

In response to an RFI, Energy Fuels stated that they would install bird netting in compliance with Colorado Division of Wildlife requirements, potentially reducing the mesh size and increasing the number of fasteners to keep the netting in place. The smaller mesh size will result in more net material per unit area over the ponds. Not only will this place additional strain on the net support structures, it will also reduce the amount of sunlight that reaches the ponds, thus reducing evaporation and providing Energy Fuels with a potential disincentive for maintaining the nets. Finally, Energy Fuels states, "these fasteners are designed to release under ice or wind strains so that the supporting structures and cables are not damaged" (Energy Fuels Resources, 2010c, p. 7), further confirming that these nets are not built to withstand conditions that may occur regularly at the mill site.

In the semi-arid climate at the mill site, the open water of an evaporation pond will attract birds and wildlife, because they cannot distinguish between clean water bodies and highly acidic evaporation ponds. We believe that Energy Fuels has underestimated the total cost of net maintenance and replacement and overestimated the effectiveness of the bird netting. While the bird balls proposed for tailings impoundments are a better alternative, they also severely reduce evaporation, reducing their viability for the evaporation ponds. As discussed in the previous section, we have found that hazing is typically not effective in the long term because it is labor-intensive and requires more regulatory oversight than is practical. Overall, we believe that the netting described in the mill plan is unlikely to be an adequate long-term solution to prevent exposure of birds and wildlife to the highly toxic raffinate in the evaporation ponds.

3.3 Pond Liners

In the previous memorandum, we discussed potential long-term problems with leakage from tailings impoundments and evaporation ponds. To review, Energy Fuels proposes lining the evaporation and tailings impoundments with double liners and installing leak detection systems that detect liquid in sumps between the liners. Liners with leak detection systems have been used at uranium mills for many years, but the upper and lower liners could, and often do, fail. According to the U.S. Environmental Protection Agency (U.S. EPA, 1994, p. 46), "leakage can occur through synthetic liners because of shrinkage, faulty seam construction, stress loading, exposure to UV radiation, or improper planning and construction of the sub-grade."

Leakage from lined impoundments is an ongoing problem at other uranium mills. For example, at the White Mesa mill in Blanding, Utah, the Utah Department of Environmental Quality (UDEQ) inspectors found tailings cells with torn liners, improperly designed and constructed liners, and liners with spikes nailed through them to keep them in place (Morton, 2000a, 2000b). Leak detection systems were underdesigned, not functioning, or missing entirely (Morton, 2000b). UDEQ estimated that, on average, the leak detection systems would allow 200,000 gallons per acre per day to leak to groundwater from these impoundments without being detected. Despite the presence of lined impoundments, concentrations of manganese, selenium, and uranium exceeded water quality standards in multiple wells at the White Mesa site (IUC, 2006).

CDPHE recently detected a uranium plume in groundwater downgradient of a lined impoundment at the Cotter Corporation's Cañon City mill, as well, resulting in a notice of violation of its operating permit (CDPHE, 2008). Identifying the sources, fate, and transport pathways of the plume have proven to be challenging, with John Hamrick, Cotter's vice president of milling, stating, "The original theories of where contaminated groundwater is moving…have been proven inaccurate. Any remedies proposed six to twelve months ago…would not have achieved the goal of contaminated water interception" (Hamrick, 2010).

While the source of this and other groundwater plumes is often contested, it is undeniable that contaminated shallow groundwater is a common occurrence at mill sites even if tailings impoundments and evaporation ponds are lined. Energy Fuels has not acknowledged this fact in their proposal, and they have not designed any site-wide leak detection and confinement systems. In fact, Energy Fuels considers groundwater a "*de minimus*" pathway in their exposure pathways report, because they assume that liners will prevent leaks to groundwater and remedial measures will limit the spread of contamination if it should occur (SENES Consultants, 2010).

We concur with CDPHE's stated concern that the application failed to address any potential pathway to groundwater or surface water from spills and leaks. Moreover, we do not believe that the SENES Consultants' (2010) revised pathways report adequately addressed these potential pathways. The Golder Associates (2010) groundwater monitoring addendum no. 1 states that aquifer testing was not conducted on alluvium because groundwater was not encountered. However, when reviewing the groundwater monitoring addendum no. 2 (Energy Fuels Resources, 2010a), we noted that monitoring well MW-2, completed to a depth of 25 ft, contained 1–3 ft of water both in October 2007 and April 2008. There are very few shallow wells at the site, but the fact that one of them contained water in two separate sampling events suggests that perched shallow groundwater may at times exist under the mill site.

Surface water monitoring addendum no. 1 (Energy Fuels Resources, 2010e) contains additional evidence that suggests a potential shallow groundwater pathway at the site. Energy Fuels monitored surface water at four site locations (S-1 through S-4). Two of these sites (S-3 and S-4) consistently contained surface water after rain events, with each station recording surface runoff after as little as 0.2" of rain. The drainage area contributing to S-4 is the largest of the four monitoring stations, and this station would therefore be expected to have the most water during rainfall events. Station S-3, however, has one of the smallest contributing areas and would not be expected to transmit as much water for a given rain event. While we have not visited the site, we note from aerial photographs that Station S-3 appears to be a highly incised channel. These data suggest that the higher frequency of surface water at S-3 may be related to the transmission of water through shallow groundwater pathways. Thus, based on multiple lines of evidence, we believe that Energy Fuels is underestimating the potential for leakage of contaminants from site facilities to perched shallow groundwater and possible subsequent movement of contaminants from perched groundwater to surface drainages and deeper groundwater.

Given the history of other mine sites, we believe that Energy Fuels should plan for contaminant releases to surface drainages and groundwater and include multiple control measures as part of the permitting process. The SENES Consultants' (2010) exposure pathways report mentions that "mentoring wells" (which presumably are monitoring wells) will be installed at the site, but they do not reference a specific plan that describes the number, depth, and frequency of monitoring. We believe that a detailed shallow groundwater monitoring plan should be provided, and we suggest that pressure transducers be installed in each well, continuously monitoring for the presence of groundwater. If contaminated liquids are released from the property, potentially creating a shallow plume of contaminated groundwater, the downgradient wells could be converted to pumping wells to help contain the contaminant plume before contamination spreads offsite. It is imperative that accidental releases to groundwater be intercepted before contaminated groundwater leaves the property and ultimately is released into downgradient surface water bodies.

The following section discusses additional aspects of contingency planning that we believe are lacking.

4. Addressing Future Problems

4.1 Adaptive Management

As we discussed in our previous comments, modern mining and milling operations should have adaptive management plans, in which they acknowledge that engineered solutions do not always work as planned, and they should include contingencies for proactively addressing the problems that arise. The U.S. Department of the Interior technical guide for adaptive management (Williams et al., 2007) recommends careful and thorough monitoring with a flexible, iterative decision-making process for addressing any changes or problems that arise. In the original Piñon Ridge mill plan, Energy Fuels and its contractors presented a plan with an engineered solution for all aspects of the milling process. Impoundments will be lined, the ground surface will be graded, it will be a zero discharge facility, and after 40 years, they will implement their closeout plan and walk away. They have assumed that these engineered solutions are failsafe and that no additional contingency planning is necessary.

In the RFIs, CDPHE raised many questions about these assumptions and pointed out several deficiencies in the plans. We concur with these concerns, and we do not believe that Energy Fuels has adequately addressed them. In the previous section, we mentioned the need for additional groundwater monitoring and, preferably, containment, should the facility fail to maintain zero discharge, as planned. We believe that a modern milling facility should acknowledge that releases are likely, given the nature and track record of the industry. The proponent should include an adaptive management plan in which they discuss how they will monitor for releases, and propose alternatives for addressing problems as they arise. Adaptive management strategies and reasonable worst-case contingency plans should also address water availability, netting maintenance and replacement, alternative exclosure technologies for evaporation ponds if netting fails, water treatment facilities to treat potentially contaminated groundwater and stormwater, and waste relocation if a liner in a tailings impoundment or evaporation pond cell is breached. Absent an adaptive management plan and more extensive monitoring, releases may not be detected and reported in a timely manner and addressed before extensive environmental contamination occurs.

4.2 Remediation Costs

Without adequate contingencies, monitoring, and a comprehensive adaptive management plan, we believe the public is at risk of inheriting this mill and its problems should the planned mitigation measures fail. In general, the mining and milling industries have poor track records of containing and reporting contaminant releases, and expensive remediation has been required. Often, companies that caused problems have declared bankruptcy, leaving state and federal agencies responsible for the design, implementation, and cost of cleanup.

In RFI No. 3, CDPHE (2010b, p. 8) correctly noted, "while releases may not be of particular health risk, the financial risks of cleanup of spills and accidents can be considerable when protecting the soil, air and water from degradation." In response, Energy Fuels simply agreed with the statement and said that economic considerations are not in the scope of their risk assessment. We have not seen adequate discussion of economic considerations. The costs of environmental cleanup can quickly exceed the gains from milling operations. It is imperative that all costs, including contingency measures to prevent releases, are within the budget of the mill plan and that an appropriate bond is included.

Data from historic uranium mill tailings remediation under the Uranium Mill Tailings Remediation Act (UMTRA) demonstrate that remediation of mill tailings is extremely expensive. The U.S. Department of Energy's Energy Information Administration summarized the cost of uranium mill remediation across the United States. Although the costs were highly variable between sites, we developed a general first-order estimate of uranium tailings remediation cost by dividing the total remediation cost by the total amount of yellowcake produced at all UMTRA sites. The total cost of remediation through the end of 1999 was $1.48 billion to remediate the tailings generated from the production of 116.5 million pounds of U_3O_8 yellowcake (Figure 2;

Remediation Project (Mill Site Name, State)	Uranium Ore Processed		Disposal Cell	
	Ore (Million Short Tons)	Uranium Production (Million Pounds U_3O_8)	Remediated Material Volume (Million Cubic Yards)	Total Cost [A] (Thousand U.S. Dollars)
Ambrosia Lake (Phillips), NM [B]	3.05	13.02	5.20	39,961
Belfield, ND	0.05	0.34	C	C
Bowman, NM	0.08	0.61	C	C
Burrell, PA	D	D	0.07	D
Canonsburg, PA	E	E	0.19	47,591
Durango, CO	1.61	7.85	2.53	67,618
Edgemont, SD	1.98	6.86	3.00	5,411
Falls City, TX	2.72	8.66	5.80	56,254
Grand Junction, CO	2.28	11.69	4.43	504,048
Green River, UT	0.18	0.83	0.38	23,633
Gunnison, CO	0.54	1.45	0.74	58,917
Lakeview, OR	0.13	0.34	0.94	33,325
Lowman, ID	0.20	0.37	0.13	18,434
Maybell, CO	1.76	4.03	3.50	63,528
Mexican Hat, UT	2.20	11.38	3.48	54,482
Monument Valley, AZ	1.10	0.77	0.93	24,126
Naturita, CO	0.70	3.18	0.79	86,332
Rifle, CO [H]	2.70	16.54	3.76	119,165
Riverton, WY	1.06	3.89	1.79	49,664
Salt Lake City, UT	1.69	9.57	2.80	94,165
Shiprock, NM	1.53	7.42	2.80	24,771
Slick Rock, CO [J]	0.63	2.68	0.86	50,428
Spook, WY	0.19	0.35	0.32	10,106
Tuba City, AZ	0.80	4.70	1.40	34,143
Total and Averages:	**27.17**	**116.53**	**46.07**	**1,476,340**

Figure 2. Cost to remediate uranium mill tailings under UMTRA.

Source: Reproduced from the U.S. DOE (2005) Summary Table.

U.S. DOE, 2005). An approximate unit cost of remediation is thus $1.48 billion/116.5 million pounds = $12.7 per pound of yellowcake produced.

According to their environmental report, Energy Fuels Resources (2010b) anticipates producing about 2,200 pounds of yellowcake per day at the Piñon Ridge mill. Assuming they are in production 350 days per year, this equates to 770,000 pounds per year. If we further assume that they produce 770,000 pounds per year for 40 years (which assumes a Phase 1 production level for the entire time), they would produce approximately 30.8 million pounds of yellowcake. At $12.7 per pound of yellowcake produced, a first-order approximation of the cost of tailings remediation is about $390 million. Although this calculation is based on simple averages from a dataset that is highly variable, it provides an order of magnitude estimate of the cost of tailings remediation. These costs do not include remediation of evaporation ponds, groundwater, surface water, or on-site soils, any or all of which may also be contaminated after 40 years of milling operations. Therefore, this estimate could be considered conservative (i.e., low).

The UMTRA data (Figure 2) provide a rough basis for bonding requirements at this site. With no adaptive management plan and few contingencies for proactively addressing potential contaminant releases, coupled with the history of contaminant releases and bankruptcies in this industry, it is reasonable to require the posting of a bond of at least several tens of millions of dollars, commensurate with unit cleanup costs as summarized in UMTRA documents (Robinson, 2004; U.S. DOE, 2005). The State should be certain that taxpayers will not be burdened with the cleanup bill.

5. Qualifications of the Authors

Below we present the qualifications of the authors of this memorandum.

James Holmes, MS, is a hydrologist with expertise in contaminant fate and transport, acid mine drainage, and water quality modeling. Over the past 18 years, he has worked at numerous hard rock mining sites as an employee of Stratus Consulting, Stratus Consulting's predecessor company, and as an employee of the U.S. Army Corps of Engineers. His research has included hydrograph separation in stormflow, geochemical mixing models, and sources of acid mine drainage. He has extensive field experience designing studies of flow measurement, contaminant loading, and water quality at mining and milling sites. He has evaluated environmental impacts at several large mining and milling operations, including the Clark Fork Complex in Montana; the Bunker Hill/Coeur d'Alene Complex in Idaho; the Upper Blackbird Mining District in Montana; the Ray Mine in Arizona; the Tri-State Mining District in Missouri, Kansas, and Oklahoma; and at uranium mining and milling sites in New Mexico. He also managed initial natural resource damage assessment work at the Hanford site in Washington, evaluating the fate and transport of radionuclide releases. Mr. Holmes holds an MS in earth sciences from Dartmouth College and a BA in environmental biology from Middlebury College.

Ann Maest, PhD, is an aqueous geochemist with expertise in the fate and transport of natural and anthropogenic contaminants in groundwater, surface water, and sediment. She has over 20 years of research and professional experience as a geochemist and has worked on natural systems as well as on systems that have been impacted by industrial activities. Dr. Maest's research has included studies of metal-organic interactions, metal and metalloid speciation, water-rock interactions, redox geochemistry in surface water and groundwater, and radionuclide fate and transport in groundwater and aquifer materials. The results of her research have been published in numerous articles in peer-reviewed journals, including *Applied Geochemistry, Canadian Journal of Fisheries and Aquatic Sciences, Chemical Geology, Applied and Environmental Microbiology,* and *Environmental Science and Technology*. She received the Adrian Smith Lecturer in Applied Geochemistry from the University of Waterloo in 1999. Dr. Maest has served on a number of national and international committees, including several National Academy of Sciences committees related to mining and minerals research issues and international committees on mining and sustainable development. She was recently elected to a second three-year term on the National Academy of Sciences Committee on Earth Resources. Dr. Maest holds a PhD in geochemistry and water resources from Princeton University and an undergraduate degree in geology from Boston University.

Constance Travers, MS, is a hydrogeologist with 23 years of experience in hydrogeology, water resources, and environmental chemistry. She has extensive experience in the development, testing, and application of numerical models used in predicting the mobility of water and inorganic and organic contaminants in surface and subsurface water. Ms. Travers has developed vadose zone, surface water, and groundwater models ranging in complexity from conceptual hydrologic models to three-dimensional numerical models of regional flow systems. Her expertise in groundwater flow, contaminant chemistry, and transport and fate processes has been used extensively by litigation teams involved in environmental lawsuits. Ms. Travers has worked on subsurface fate and transport issues to support site characterization, remedial investigations, and feasibility studies. She has directed multidisciplinary teams to assess the water quality impacts of hard-rock mining operations, including assessment of the water quality and ecological risks associated with the lakes that form in dewatered open pits, the effects of tailings impoundments and waste rock storage facilities on receiving waters, and the impact of mine dewatering on groundwater and surface water resources. She has managed hydrologic field investigations including sampling of surface water, sediments, soils, and groundwater; monitoring well installation; aquifer testing, cone-penetrometer; and Geoprobe work. Ms. Travers holds an MS in applied hydrogeology and a BS in geology from Stanford University.

Cameron Wobus, PhD, is a geomorphologist and surface and groundwater hydrologist. His areas of specialty include surface water and groundwater hydrology, sediment transport, and numerical modeling. Dr. Wobus has developed and implemented watershed-scale hydrologic monitoring and models, developed numerical models of sediment transport and river incision, and evaluated contaminant fate and transport pathways in surface and subsurface water. His publications have appeared in *Nature, Earth and Planetary Science Letters, Geology,* and the *Journal of Geophysical Research*. Dr. Wobus holds a PhD in earth sciences from the Massachusetts Institute of Technology, an MS in earth sciences (hydrogeology) from Dartmouth College, and an AB in economics and geology from Bowdoin College.

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