Department of Energy Office of Legacy Management Progress on Defense-Related Uranium Mines Program - 18119

Russel Edge* and John Elmer**
*US Department of Energy Office of Legacy Management
**Navarro Research and Engineering, Inc.

ABSTRACT

The Defense-Related Uranium Mines (DRUM) Program provides the structure and basis for the US Department of Energy Office of Legacy Management (LM) to manage the verification and validation (V&V) of defense-related uranium mines (mines) that provided ore to the Atomic Energy Commission from 1947 to 1970. V&V activities are conducted to fully understand the scope of potential problems posed by these mines by determining their location, reclamation or remediation status, and potential impacts to public safety, human health, and the environment. Land management agencies have limited resources and have generally not conducted comprehensive inventories of abandoned uranium mines, thus adding to the need to undertake this program.

LM has entered into memoranda of understanding (MOUs) with the US Bureau of Land Management (BLM) and US Forest Service (USFS) to facilitate a better understanding of the scope of the problem posed by these mines. Currently, LM has executed MOUs with the BLM state offices in Colorado, New Mexico, Utah, and Wyoming and the USFS Rocky Mountain Region, which includes the national forests in Colorado, Wyoming, and South Dakota. This collaborative effort with partner agencies has led LM to develop a V&V Work Plan that describes the numerous activities and types of data to be collected at the mines. V&V activities verify actual mine location, collect coordinates of mining-related features, collect radiological data and soil samples, identify potential physical safety hazards, prioritize mines using a risk-based screening approach, and report the information to partner agencies. The partner agencies may use the reports to assess priorities and determine if any further action is warranted.

The DRUM Program goals are to:

- Improve data quality and content in the LM national inventory of abandoned uranium mines
- Conduct site-specific reconnaissance at mines for data verification and validation
- Exchange mine information with other federal agencies and state governments to help address mines presenting the greatest risks
- Develop reports for each mine that will contain a risk scoring assessment to help each agency develop priorities

The preliminary risk screening methodology was based on a joint effort between LM and BLM to develop factors that would be based on field observations, field data, and laboratory data using a multiple-lines-of-evidence approach. The multiple-lines-of-evidence assessment allows land managers the opportunity and flexibility to query specific criteria and make rankings based on specific priorities. The risk screening for each mine is based on evaluating the primary hazards of physical safety and risks to human health and several modifying factors that include accessibility and ecological/environmental risks.

Gamma radiation scans are performed across the disturbed area of the mine, and soil samples are taken from waste rock piles and drainages, when applicable. This paper presents the results of performing inventory, environmental sampling, and risk ranking along with other accomplishments and lessons learned during the initial year of V&V activities and reporting.

INTRODUCTION

The Defense-Related Uranium Mines (DRUM) Program provides the structure and basis for the US Department of Energy (DOE) Office of Legacy Management (LM) to manage the verification and validation (V&V) of mines that provided ore to the Atomic Energy Commission (AEC) from 1947 to 1970. DOE obtained its authority for the program under Section 3151 of the National Defense Authorization Act for Fiscal Year 2013. The Act mandated that DOE conduct a review of the location, status, and risk posed by abandoned uranium mines (each hereafter also referred to as a "mine") and consult with other federal agencies in preparing a DRUM Report to Congress. DOE finalized the report in August 2014 identifying 4225 DRUM mines in 19 states. Figure 1 shows the major mining districts and mines of the program, while Figure 2 shows the relationship of the amount of ore produced in each state versus the number of mines within that state.

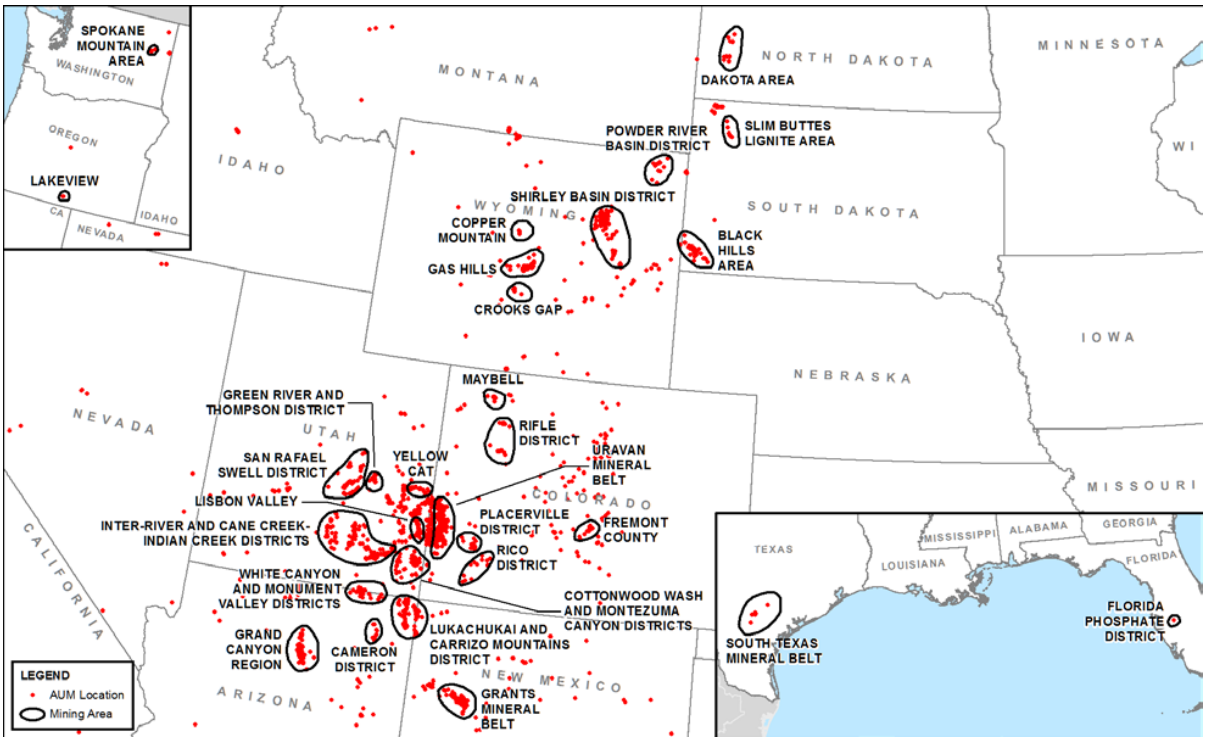

Figure 1. Location of DRUM Mines in Relation to US Mining Districts

As shown in Figure 2, although most of the mines (approximately 69%) are located in Utah and Colorado, the majority of the production (approximately 47%) occurred in New Mexico on a much smaller number of mines.

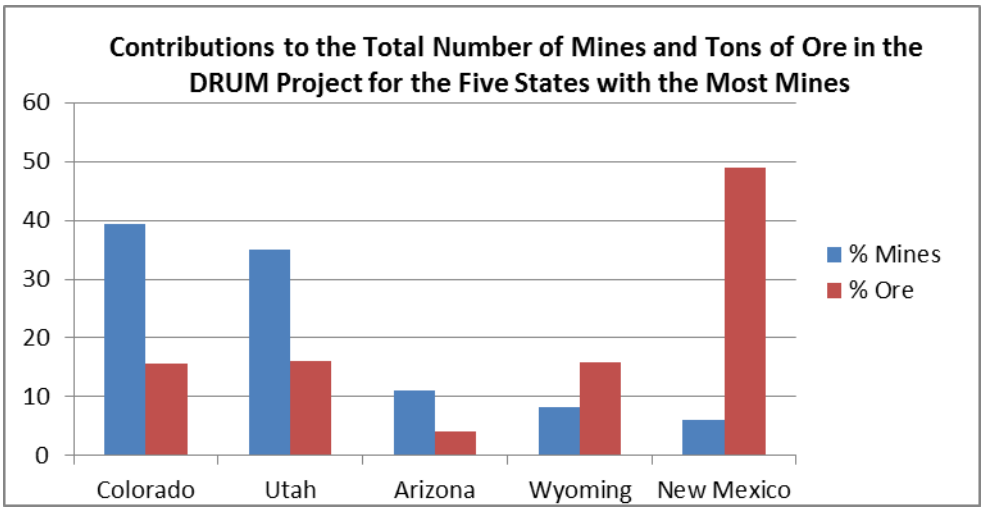

Figure 2. Total Number of Mines and Tons of Ore Produced for the Five States with the Most Mines

LM developed the DRUM Program and established partnerships with the US Bureau of Land Management (BLM) and US Forest Service (USFS) to perform V&V on federal lands managed by those agencies. To date, DOE has signed memoranda of understanding (MOUs) with BLM and USFS. LM has also established partnerships with state abandoned mine land (AML) programs to obtain assistance in inventorying DRUM mines located primarily on private, mixed-ownership, and state lands.

To facilitate V&V activities, LM has developed a V&V Work Plan with BLM and USFS to guide field activities and collect the information needed for the agency to assess priorities and determine if future actions are warranted. As part of the V&V Work Plan, an approach to assessing risk at every mine was developed. Risk ranking tables were developed to evaluate the primary hazards of physical safety, risks to human health and the modifying factors of ecological/environmental risk, access/suitability, and complexity/magnitude. V&V is composed of the following four steps:

1. Reconciliation—determination of the mine location, ownership, and status.
2. Inventory—locate mine on the ground, map features.
3. Environmental sampling—gamma radiation scan, composite soil sample, water sample when needed.
4. Reports—document field data, observations, risk ranking for each mine.

DOE's initial goal is to complete V&V on 2500 DRUM mines located on federally managed lands (primarily BLM and USFS) by 2022. Fieldwork is broken into geographic districts established by the land management agencies, and a field operations plan is developed for each district. The field operations plan summarizes the mines within each district, land ownership (which guides where LM can perform V&V activities), mapping and detailed information where it exists for each mine, and agency and emergency contact information. In fiscal year 2017, LM's contractor, Navarro Research and Engineering, Inc., hired four field crews and support staff to perform V&V activities. After an initial pilot program conducted during the fall of 2016 on 48 mines, V&V activities started again in August 2017. As of October 31, 2017, V&V has been completed on over 400 mines located primarily in southeast Utah and southwest Colorado.

DRUM PROGRAM

Partnerships

LM has entered into MOUs with the BLM state offices in Colorado, New Mexico, Utah, and Wyoming and the USFS Rocky Mountain Region, which includes the national forests in Colorado, Wyoming, and South Dakota. LM intends to work on DRUM mines in the state of Wyoming next year and will enter into an MOU with that BLM state office along with the appropriate USFS region.

LM has also entered into agreements with state AML programs in Colorado and Utah. The states are able to obtain inventory data on private, mixed-ownership, and state lands without individual access agreements. If LM was to work on private lands, an access agreement would be required for each property, taking months to facilitate. In addition, the AML programs have data on sites already inventoried and where reclamation activities have occurred. As discussed under "Inventory," the Utah Division of Oil, Gas, and Mining has conducted inventory on mines located on BLM-managed lands in southeast Utah, and the State of Colorado Division of Reclamation, Mining and Safety has conducted inventory on mines located in southwest Colorado.

Risk Scoring Assessment

Risk Scenario. LM worked with BLM to assemble a risk scoring assessment system for objectively evaluating observable hazards at each mine. Both LM and BLM agreed that the proper risk scenario to use would be that of a recreationalist (i.e., camper, hunter, mountain biker) staying 2 weeks on a DRUM mine site, since that is the maximum time allowed by BLM regulations. V&V activities will establish multiple lines of evidence from observational data and a human health and environmental risk screening based on radiological surveys, sampling, and analytical data. These data will be considered collectively to evaluate the risks and hazards associated with each mine.

Determining Risk Levels. BLM has developed risk-based screening levels for an adult or child receptor under a recreational use scenario [1]. In developing these recreational screening values, BLM assumed an individual would be exposed to mine-site constituents of interest (COIs) as a result of soil ingestion, dermal contact with soil, and inhalation of airborne particulates. The US Environmental Protection Agency (EPA) online risk screening level calculator was used to calculate the BLM values. Figure 3 provides a graphic representation of a conceptual site model for exposure at a DRUM mine. This figure depicts simplified exposures to human and ecologic receptors of potential mine contaminants.

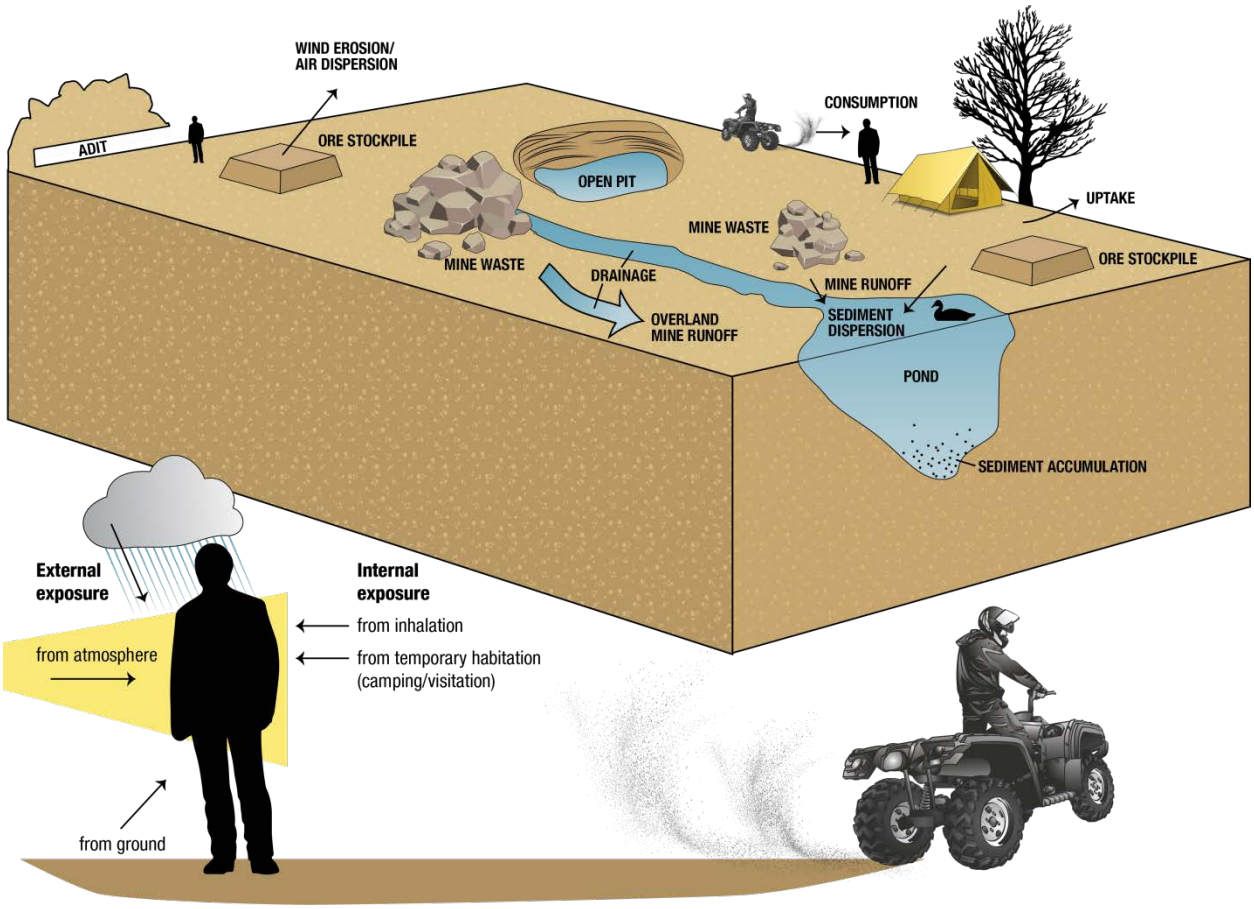

Figure 3. Conceptual Site Model for Exposure at a DRUM Mine

These screening levels are based on a conservative assumption of a recreational scenario that assumes a child or adult is potentially exposed for 14 days each year over 26 years. A concentration in soil below the screening level indicates that chemical or radiological factors at the mine-related feature should not pose an unacceptable human health risk. Where concentrations of a COI equal or exceed a screening level, the potential for elevated human health risk exists. Human health risk screening will include consideration of multiple lines of evidence to further assess the potential for complete exposure pathways. These multiple lines of evidence include ease of public access and proximity to maintained roads and evidence of past use, such as the presence of campfire pits.

The gamma radiation walkover survey is the primary methodology used to screen for potential radiological risks to human health. LM has established human health dose-based screening criteria for evaluating radiologic data collected at the mine. These criteria are also based on a 2-week recreationalist assumption.

Utilizing an analysis of the recreational future exposure scenario, a screening-level study was conducted for LM [2]. The 2-week occupation may be accumulated continuously or as a result of multiple visits during the course of a year. LM established a radiologic risk screening level of 0.25 millisievert per year (mSv/yr) [25 millirem per year (mrem/yr)], which corresponds to a gamma radiation level of approximately 64 microroentgens per hour (µR/hr) and 1 mSv/yr [100 mrem/yr] dose, which corresponds to 256 µR/hr. For the purpose of scoring mines based on gamma survey results, a lower threshold of 32 µR/hr (half of the 64 µR/hr exposure level) was used, which equates to approximately 0.125 mSv/yr [12.5

mrem] dose for a 2-week camping scenario. The 32 µR/hr level coincides approximately with EPA's protective dose level recommendation of 0.12 mSv/yr [12 mrem/yr] [3].

The screening level of 0.25 mSv/yr [25 mrem/yr] corresponds to the US Nuclear Regulatory Commission decontamination criteria for unrestricted use. A 1 mSv/yr [100 mrem/yr] dose limit is the basic international consensus (including DOE) standard for public exposure above background from all sources.

When average gamma radiation levels across the disturbed area of the mine (after background level is subtracted) are less than 32 µR/hr, potential radiological risks to both humans and environment are sufficiently low that no further evaluation of the radiological risk is required. If gamma radiation concentrations exceed 256 µR/hr, a visitor to the mine could receive the entire annual dose in a 2-week period from a single source, and radiological conditions may warrant future evaluation. For mines with gamma radiation levels between the other screening levels, the need for further evaluation would likely be made after consideration of other contributing factors such as how near the survey data values fall with respect to the upper screening level, as well as factors related to mine accessibility, mine attractiveness to visitors, and other lines of evidence.

DRUM Risk Scoring Process. The DRUM Program risk scoring process is designed to optimize risk evaluation by providing flexibility to the risk evaluator. This scoring process uses a two-part approach for identifying mines with no known hazards and for prioritizing mines with hazards into high, medium, and low priority categories. The overall approach focuses first on ranking site hazards (both physical safety and human health) and secondarily on the application of modifying factors. This approach is similar to the one used by the National Park Service for prioritizing mines on park service lands [4] but was adjusted to meet the goals of the DRUM Program (e.g., prioritizing entire mine sites, which could have one or more mine hazards, instead of prioritizing individual mine hazards). One objective of the first step is to identify mines that are at opposite ends of the hazard spectrum: (1) those that have no physical or human health hazards and can likely be eliminated from further consideration (i.e., likely that no further action is needed) and (2) those that pose clear physical hazards and/or human health hazards, and likely need action (i.e., high priority). The emphasis in this prioritization approach is to put mines into "bins" that pose similar hazards. Based on DOE's Report to Congress [5], the majority of mines on federal lands (mostly BLM land) are small (less than 91 metric tons [100 US tons] of ore produced) or small/medium (91–907 metric tons [100–1000 US tons] of ore produced). Of the small mines, about a third produced less than 9 metric tons (10 US tons) of ore and around 60% produced less than 23 metric tons (25 US tons). It is therefore likely that many of these mines have few physical or human health hazards.

As discussed below, physical and human health hazards for a mine are first designated as "none," "low," "medium," or "high" based on the severity of hazards present. These initial mine rankings can then be adjusted by application of modifying factors using a multiple-lines-of-evidence approach to arrive at the final mine ranking. Modifying factors are (1) potential ecological/environmental impacts, (2) access/suitability criteria, and (3) hazard complexity/magnitude. This is shown in Figure 4.

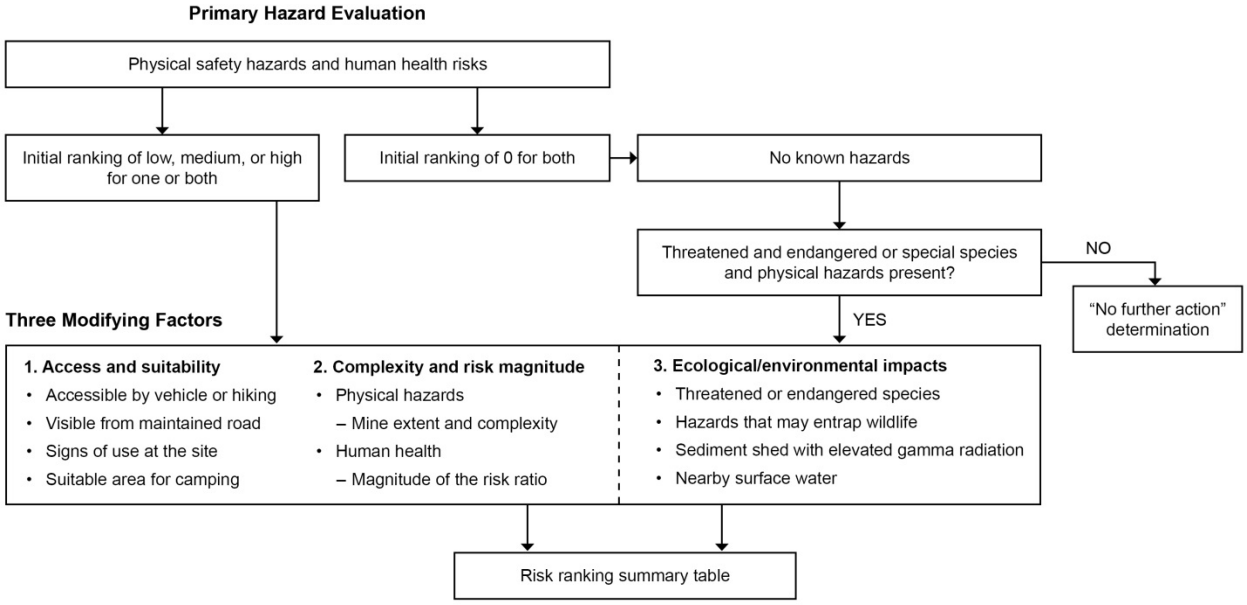

Figure 4. Risk Flow Chart

Reconciliation of DRUM Locations

Initially, the 4225 mines identified for the DRUM Program were compiled from historical AEC production records for the years 1947–1970 and from existing federal, tribal, and state databases. Data for these mines was assembled into a DRUM Program database; however, in most cases the data associated with a mine is both incomplete and potentially inaccurate. The need for increased integrity within the dataset necessitated the reconciliation process, which is geared toward correlating all pertinent location data in an effort to link a specific mine with a specific geographic point. Typical issues encountered and resolved during reconciliation include inaccurate location information, duplicate records, multiple mines listed under one record, and missing records. The reconciliation process ensures that the most accurate location data are available to inventory teams before conducting V&V activities.

The reconciliation team assesses mines within a predetermined geographic area or mining district by using multiple data sources and reference materials. The primary focus of the reconciliation team includes a determination of the mine name, number of mine workings, detailed latitude and longitude coordinates, land ownership status, and the amount of ore produced from the mine. Location data sources include AEC area economic maps and reports; topographic and geologic maps and other publications from the US Geological Survey (USGS); aerial imagery; state mining data; and other historical documents. Corroboration among several of these documents and maps is used to confirm the mine location and to further define mine-specific data. Also, mine location data are collected from partner agencies and other stakeholders, including state AML programs involved with the DRUM Program.

As expected, available information varies greatly from mining district to district. In some districts, such as BLM's Uncompahgre Field Office in Colorado, BLM staff has already visited the majority of sites, so locations of mines are established. In other areas such as the Yellow Cat District located south of Interstate 70 and north of Moab, Utah, numerous small mine complexes exist and often overlap. In addition, a few mining companies have conducted their own inventory of hundreds of abandoned uranium mines in the area, and some of the companies are willing to share their information. This can be a very complex process. For example, one mine listed in the AEC records, called the Utah Alloy Corporation, actually consisted of over 30 small individual mine sites, with only one location listed, which was

obviously in the wrong geographic area. It took numerous sources of information, including feedback from field crews, to straighten out location and names associated with each of the mines.

Collections of documents from former uranium geologists have also been extremely valuable. Through participation in local mining and geology clubs, staff members have worked with families to collect hundreds of documents (often original claim maps) that have not been found elsewhere. Maps are scanned and preserved for future use.

Inventory

Inventory team site visits are intended to maximize the efficiency of the field effort by collecting information that supports the environmental sampling effort. Because the inventory teams usually consist of two individuals vs. the large environmental sampling team, if it takes hours to locate a mine, then fewer hours are wasted. Ideally, inventories are typically conducted before environmental sampling teams visit a mine. The inventory team verifies that the mine visited is the intended target, defines the mine's disturbed area, uses a GPS unit to locate mine features, and takes photos. The GPS activity includes completing a checklist of the information collected by the inventory team. Because much of the inventory effort is based upon observations of existing conditions, the teams use the checklist to ensure that all required information has been collected before they leave a mine. Figure 5 shows a geologist locating an adit on a small mine.

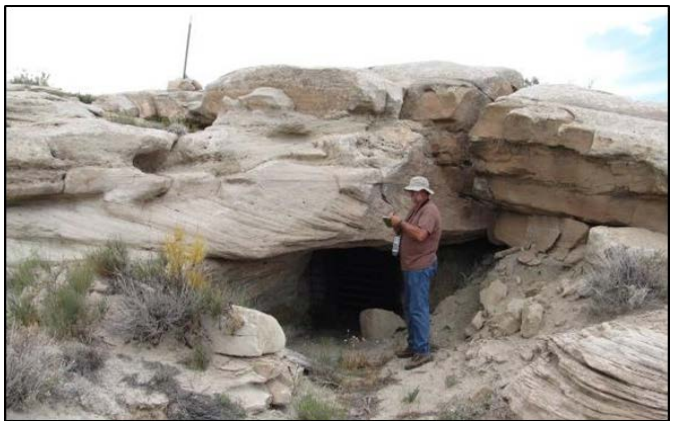

Figure 5. Geologist Locating an Adit on a Small Mine in the Yellow Cat Area of Utah

Pertinent information collected by the inventory team is transmitted to the environmental sampling team to prepare and facilitate its sampling work. Not only is the location determined, but also the size of waste rock piles that need to be sampled, and if seeps occur or surface water exists near the mine. Consequently, the sampling team can determine and plan for the number of soil and water samples, and lay out sampling grids, before their field visit.

Partner organizations have performed similar efforts, which have been very useful for the DRUM Program. To date, the state of Utah Division of Oil, Gas, and Mining has conducted inventory on 24 DRUM mines located on BLM-managed lands within the Red, White, and Fry canyons and Deer Flat mining districts located 50 miles west of Blanding, Utah. The State of Colorado Division of Reclamation, Mining and Safety has conducted inventory on 78 DRUM mines on private lands in BLM's Uncompahgre Field Office jurisdiction, located in southwest Colorado, while the State of New Mexico has completed inventory of six DRUM mines in the Grants Mining District.

Environmental Sampling

During environmental sampling, soil and water (as needed) samples are taken, radiological (gamma radiation) walkover surveys are performed over the disturbed area of the mine, and the ecology of the mine is assessed.

Determination of Background. Background levels for COIs and gamma radiation can vary for different mines because background is dependent on factors such as the geological formation and the occurrence of mineralized surface features. Background data is collected on a regional basis to the extent that it adequately characterizes specific mine locations within a region or mining district. A single background location is chosen as a regional marker for multiple mines if the data point meets specific criteria. The criteria require that a suitable background location will consist of an undisturbed area with similar soil and geologic conditions that is located in the same region or district as the mine or group of mines being investigated.

Soil Samples. Soil samples are collected from all but the smallest of piles (those measuring less than 9.3 square meters [100 square feet]). The soil sampling procedure contains detailed instructions for the collection of solid samples using a 30-point sample collection strategy. USGS developed a statistically based strategy for sampling the surficial material of mine waste dumps, drainages, and background areas for use in screening and prioritizing historical abandoned mines [6]. This procedure has been adapted for use during the environmental sampling process. Soil samples are analyzed at a subcontracted analytical laboratory that is accredited in multiple states and through the Department of Defense Environmental Laboratory Accreditation Program.

Gamma Walkover Surveys. Gamma walkover surveys are performed to obtain radiological data that represent the magnitude and spatial distribution of gamma radiation across the mine [7]. Because of the natural mineralization surrounding most mines, spatial variability in soil radionuclides is expected to be high, potentially exhibiting order of-magnitude changes in concentrations and associated exposure rates over a distance of 6–9 meters (20–30 feet). A gamma walkover survey can identify these spatial variabilities and the resultant gamma radiation exposure rates when used in conjunction with GPS location data collection. The result map of the gamma walkover survey visually displays, in a color-coded, in contour fashion, the extent and magnitude of the gamma radiation at the mine. See Figure 6 for an example of a gamma radiation walkover survey on a DRUM mine. Levels presented in the figure are above background. This information can be used to understand the potential radiological risk to visitors, and a determination can be made about the level or category of risk involved.

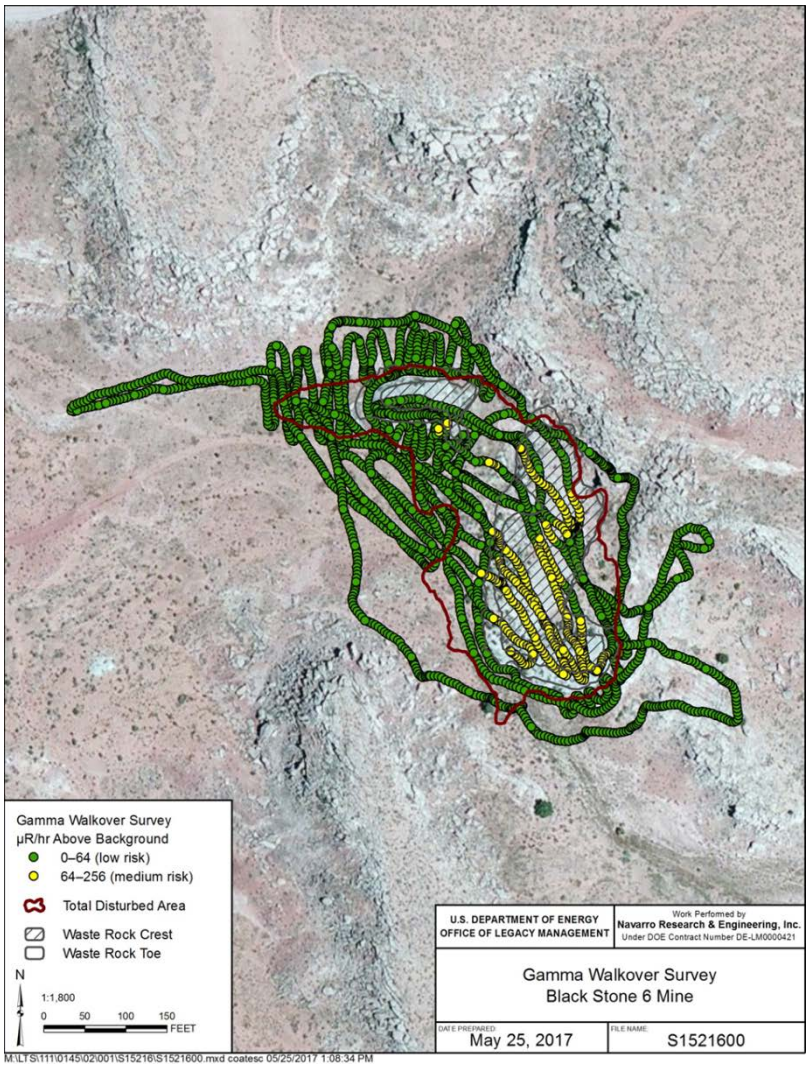

Figure 6. Example of a Gamma (Radiation) Walkover Survey

Ecological Surveys. Ecological information for each group of mines is reviewed in advance to focus field activities and address special-status species that are most likely to be present in a given area. Field teams are provided with special-status species lists and information about how to collect evidence of their presence, specific soil information, and data on surface water, wetlands, and other ecologically sensitive areas. Before field activities begin, land management agencies are consulted about potentially threatened and endangered species and critical habitat.

Evidence of flora and fauna and their potential habitat on or near the mine is collected and analyzed in relation to mine features and sources of contamination. Ecological resources include threatened or endangered species, designated critical habitat, and special-status species designated by BLM, USFS, and other agencies.

When present, surface water at a mine will potentially attract livestock and other animals, thus potentially increasing animal presence. The presence of surface water at a mine will be noted by the ecologist and trigger more targeted observations of animal use.

If evidence of threatened, endangered, or special-status species is found, a survey is performed by the ecologist. The appropriate land management agency is notified of such findings, and evidence will be recorded with photographs and field notes.

Verification and Validation Field Results

Risk Ranking. An evaluation was conducted for an initial set of 77 mines for which V&V has been completed. The mines in this initial dataset are located in Colorado and Utah and are on land managed by BLM. Detailed information on these mines was compiled into a spreadsheet that includes site name and location, site characteristics, post-mine-operation improvements, risk ranking, and clarifying comments. The risk ranking focused on the primary hazards of physical safety, radiological risk, and chemical risks but also included modifying factors (e.g., site access) that influence these primary risks. Risks were ranked relative to each with the ranking options being high, medium, low, or none/not applicable. The main observations from this preliminary analysis are:

- Over half the mines produced fewer than 907 metric tons (1000 US tons) of ore. Approximately 20% were very small, producing fewer than 23 metric tons (25 US tons) of ore. No very large mines were represented in this dataset.

- There is a general correlation with increased physical hazards and greater-production mines. However, some smaller mines also had significant physical hazards.

- Based on the sample of mines visited, the mines that were more likely to have physical hazards mitigated tended to be the greater-production mines. These activities (e.g., closing adits) did reduce the physical safety risk. However, a number of mitigated mines still present hazards because of unstable structures. A total of 17 (22%) of the 77 mines reviewed had unstable structures, mostly in the form of large wooden ore chutes (see Figure 7). In addition, the integrity of some closures has been compromised, indicating the need for periodic maintenance.

Figure 7. Collapsed Wooden Ore Chute at the Tramp 2 Mine, Club Mesa, Colorado

- The greater-production mines tend to have better access and are more complex (multiple hazards). However, there is no apparent relationship between production volume and the radiological or chemical risk ranking.

- The main risks associated with these mines are from physical safety hazards. The radiological and chemical risks are much lower based on the recreational use exposure scenario (see Figure 8). (Note that in the figure the chemical risks reflect 66 samples, since not all of the 77 mines were sampled.) The high rankings for the physical hazards were mostly influenced by open, easily accessible, and unstable adits and large unstable structures associated with historical mining operations.

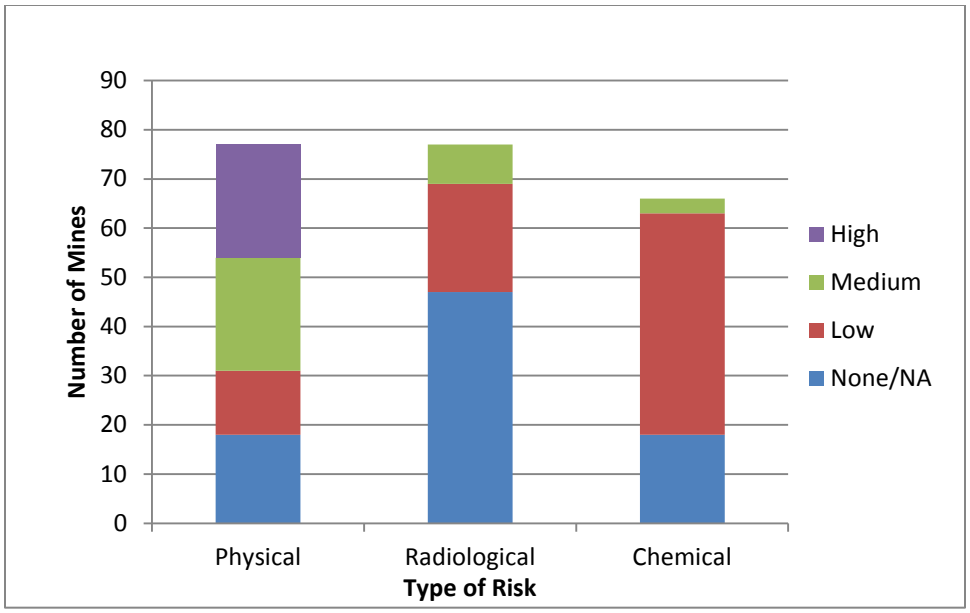

Figure 8. Comparison of DRUM Mine Risks

Other Observations Pertaining to the Evaluation of DRUM Mines. Utilizing the limited set of data that has been evaluated in detail and information in Ref. [5] and other documents, the following overall observations were made:

- Based on DOE's current DRUM database, approximately 10% of the mines are identified as "reclaimed," while the status of the rest is categorized as "unknown." Of the 77 mines evaluated, 12 of them have been partially or fully reclaimed (approximately 16%). The only reliable way to fully identify the status and hazards of these mines is to complete the field visits to the remaining mines, which is one of the primary objectives of the DOE V&V program.
- Although numerous physical hazards have been found, to date, only one very severe hazard (see Figure 9) has been identified at a mine that required immediate reporting to the land management agency. This could change when mines in other locations are inventoried.
- Other unusual features reported to land management agencies include graves (piled rocks, some marked) and abandoned vehicles in remote areas.
- Of DOE's current DRUM mine inventory, it is estimated that approximately one-third of the mines are located on land that has the potential to be used for residential use (e.g., private, Native American lands) [5]. Residential use screening criteria may be appropriate at these mines. Residential use criteria for chemical and radiological constituents would be considerably lower than the recreational criteria used in this evaluation. The use of lower screening values could result in a number of mines with elevated radiological and/or chemical risks.

Figure 9. Daisy 2 Mine, Large Subsidence Feature next to the Road, Red Canyon, Utah

CONCLUSIONS

In conclusion, there is considerable diversity in the physical hazards posed by the mines that have been visited so far. Although higher production volumes seem to correlate with the presence of physical hazards at mines that have not been safeguarded, other factors may prove to be useful predictors of hazards as well (e.g., period when mine operated, geology of the mining district). In addition, although some physical hazards may have been mitigated, other physical hazards such as wooden structures may remain. V&V activities continue to demonstrate the need for the DRUM program to collect field data and provide risk scoring assessments to help each agency develop priorities.

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