U.S. DEPARTMENT OF ENERGY

Defense-Related Uranium Mines

Report to Congress
August 2014

United States Department of Energy
Washington, DC 20585

Message from the Secretary

Section 3151 of the National Defense Authorization Act for Fiscal Year 2013 directed the Secretary of Energy, in consultation with the Secretary of the Interior and the Administrator of the U.S. Environmental Protection Agency (EPA), to undertake a review of, and prepare a report on, abandoned uranium mines in the United States that provided uranium ore for atomic energy defense activities of the United States (the mines).

The U.S. Department of Energy (DOE) worked actively with the U.S. Department of the Interior and EPA on the report development. DOE also solicited and provided numerous opportunities (by creating a website, hosting webinars, issuing quarterly newsletter updates, and participating in abandoned mine and uranium forums) for other agencies, states, affected tribes (with expanded communications with the Navajo Nation) and the interested public to provide input into development of the Report. As described in Section 3151, the Report addresses five issues:

- the location of defense-related abandoned uranium mines on federal, state, tribal, and private lands;
- the extent of radiation hazards, other public health and safety threats, and environmental degradation caused, or may have been caused, by the mines;
- a priority ranking to reclaim and remediate the mines;
- the potential cost and feasibility of reclamation and remediation in accordance with applicable federal law; and
- the status of any mine reclamation and remediation efforts.

As the statute requires, DOE submits this Report to the Senate and House Committees on Armed Services, the Senate Committee on Energy and Natural Resources, the House Committee on Energy and Commerce, and the House Committee on Natural Resources via the following members of Congress:

- **The Honorable Carl Levin**
  Chairman, Senate Committee on
  Armed Services

- **The Honorable Howard P. McKeon**
  Chairman, House Committee on
  Armed Services

- **The Honorable Adam Smith**
  Ranking Member, House Committee on
  Armed Services

- **The Honorable James M. Inhofe**
  Ranking Member, Senate Committee on
  Armed Services

- **The Honorable Mary Landrieu**
  Chairman, Senate Committee on Energy
  and Natural Resources

- **The Honorable Fred Upton**
  Chairman, House Committee on Energy
  and Commerce

- **The Honorable Doc Hastings**
  Chairman, House Committee on
  Natural Resources

- **The Honorable Lisa Murkowski**
  Ranking Member, Senate Committee on
  Energy and Natural Resources

- **The Honorable Henry Waxman**
  Ranking Member, House Committee on
  Energy and Commerce

- **The Honorable Peter DeFazio**
  Ranking Member, House Committee on
  Natural Resources

If you have any questions, please call me or Bradley R. Crowell, Assistant Secretary, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Ernest J. Moniz

Executive Summary

This Report to Congress, prepared by the U.S. Department of Energy (DOE), is in response to Section 3151 of the National Defense Authorization Act for Fiscal Year 2013, which states, in part:

> The Secretary of Energy, in consultation with the Secretary of the Interior and the Administrator of the Environmental Protection Agency, shall undertake a review of, and prepare a report on, abandoned uranium mines in the United States that provided uranium ore for atomic energy defense activities of the United States.

For this Report, DOE identified abandoned uranium mines (mines) from which uranium ore was extracted for atomic energy defense-related activities of the United States from 1947 to 1970.[1] Some mines listed in this report have been reclaimed and remediated. Others have current operating permits but may have abandoned mine site features within the permitted area that are not yet remediated. A mine may include associated mining-related features such as mine adits and shafts (mine openings), surface pits and trenches, highwalls, waste-rock piles, structures, production and ventilation shafts, debris piles, and onsite roads. To be complete and because of the uncertainties described above, DOE has chosen to include all uranium mines that provided ore for defense activities. For this Report, a mine does not include offsite impacts or features such as ore-buying stations, ore transfer stations, or ore used in structures, roads, and general fill.

The mines were assigned to production-size categories ranging from Small (0–100 tons) to Very Large (>500,000 tons) based on the amount of uranium ore sold to the U.S. Atomic Energy Commission (AEC). The categories were developed in lieu of developing cost and risk evaluations for individual mines. DOE developed the range of features (e.g., portals, structures) for each production-size category using data from 343 past mine reclamation projects and by visiting 84 mines in six states, collecting site-specific data, comparing with agency databases, and documenting the size and number of features per mine.

Location

Starting with AEC production records and supplementing them with information from federal- and state-agency databases, a tribal abandoned mine land program, private company and

[1] Location and other relevant data were provided by numerous agencies including the U.S. Bureau of Land Management, the U.S. Environmental Protection Agency (EPA), the Navajo Nation, and abandoned mine land (AML) programs of states and other federal agencies. The most significant reason for differences in the number of mines reported is that some AML programs count individual mine features (e.g., an adit, a waste rock pile). In addition, EPA's definition of mines can include ore processing facilities. In the case of uranium mines, the mills that processed the ore have been or are being remediated under the Uranium Mill Tailings Radiation Control Action of 1978, as amended.

public input, and maps and other documents, DOE determined that 4,225 mines provided uranium ore to the AEC from 1947 to 1970. Of the 4,225 mines, 26 mines could not be located. Approximately 69 percent of the mines are in Colorado and Utah, with another 23 percent present in Arizona, New Mexico, and Wyoming. Of the 75.9 million total tons of uranium ore produced for defense-related purposes, New Mexico mines led with over 35 million tons. New Mexico was followed by Colorado, Utah, and Wyoming, each with more than 11 million tons. Nearly half of the mines are located on federal land managed by the U.S. Bureau of Land Management (BLM). Approximately 11 percent of the mines are on tribal lands.

Assessment of Risk to Human Health and the Environment

Due to limited data availability, risk assessments were conducted for an "average" mine for each of five mine-size categories based on the amount of ore produced, to evaluate the potential radiological risk associated with the mines. An "average" mine was developed for this evaluation by defining the dimensions of the sources of potential exposure (e.g., waste-rock piles and surface soil contamination) for each mine-size category. A conceptual site model was developed to identify potential sources of contamination, plausible receptors, and exposure pathways. The receptors evaluated were an onsite resident (included two scenarios: onsite resident A with a dwelling on top of a waste-rock pile and onsite resident B with a dwelling on the mine site area and with waste-rock material used in the dwelling foundation), an offsite resident, a recreational visitor, a reclamation worker, and an occasional visitor. Potential pathways of exposure evaluated include inhalation of radon and particulates; external gamma radiation; incidental ingestion of soil; and ingestion of plant foods, meat, and milk (for both onsite and offsite resident receptors). The groundwater pathways were not calculated as groundwater conditions tend to be unique to each mine and should appropriately be done on a site-specific basis. Where groundwater contamination from mines definitely occurs, it could contribute to the overall risk. However, most Small and Small/Medium mines were likely developed above the water table, and some “wet” mines are located in areas where groundwater have high naturally occurring levels of the same constituents (including radioactive elements) that are typically associated with uranium mines.

Radon inhalation was the largest contributor to the risk estimates for all receptors, followed by exposure to external gamma radiation. Risks from other pathways (e.g., ingestion of plants, meat, milk, and soil) are small compared to the radon and external gamma radiation pathways. Of the five receptors evaluated, the risk estimates for the onsite resident and reclamation worker exceeded 10^{-4}, which is the upper end of the U.S. Environmental Protection Agency’s (EPA’s) acceptable range of 10^{-6} to 10^{-4} for an incremental lifetime cancer risk. EPA’s risk range was used for comparison in this risk evaluation. For the onsite resident, with estimated risks up to 10^{-1}, risks would result primarily from the inhalation of radon that emanates from the waste-rock pile or foundation material and diffuses into the house. Risks for the reclamation workers are expected to be lower than the estimates developed in this Report, as risk reduction from required worker protection measures was not taken into account for the risk calculations.

The potential physical hazards that people could encounter were evaluated by determining the number of people that resided at certain distances from the mines and determining the proximity of mines to schools and roads using available location coordinates (latitudes and longitudes). About 72 percent of the mines have 100 or fewer people living within a 5-mile radius of the mine. Another 24 percent of the mines have between 101 and 1,000 residents living within a 5-mile radius of the mine, leaving about 4 percent that have more than 1,000 residents within a 5-mile radius. Very little site-specific information was available on physical hazards at individual sites.

For surface water, the mine locations were evaluated by comparing their locations with those of impaired water bodies identified by states and submitted to EPA under the impaired-water-list requirements in section 303(d) of the Clean Water Act. A comparison of the mine locations with the impaired water bodies indicates that 45 mine locations (about 1 percent of the mines identified) are near or immediately upstream from an impaired surface water body.

Similarly, the evaluation of groundwater quality indicated that 44 mines (about 1 percent) are within 1 mile of a U.S. Geological Survey National Water Information System measurement site that indicates degraded groundwater quality. All 44 mines occur in areas of the United States where other types of mining are prevalent. The evaluations indicate that some mines could be in areas of both impaired surface and groundwater quality. A definite conclusion could not be drawn between water impairment and the mine sites based on the information evaluated.

Potential impacts of the mines on ecological resources were evaluated by a review of (1) the radiological risks to ecological receptors exposed to potentially contaminated soils, waste-rock piles, and water and (2) the use of underground mines by bats. Most concentrations of chemical and radiological constituents and absorbed doses at mines are below ecological protection levels.

Prioritization of Reclamation and Remediation

In preparing this Report, existing information was collected and reviewed, including regulatory drivers for the reclamation/remediation of mines; regulatory history and status of mine waste; cleanup standards; prioritization criteria for uranium mines used by different federal, tribal, state, and local government agencies and programs; and the status of mine cleanup efforts by federal, tribal, and state agencies. Environmental hazards (i.e., those related to radiological or chemical releases) are typically identified at about 10 to 20 percent of the inventory of all hard-rock mines. Physical hazards are typically identified at as much as 70–80 percent of the inventoried hard-rock mines. Uranium mines represent about 5 percent of the abandoned hard-rock mine inventory.

Multiple government entities have conducted reclamation/remediation of uranium mines. The various approaches for addressing site hazards and setting priorities are partly dictated by the goals of the various regulatory programs, funding sources, and missions of the agencies that manage the land on which the mines reside. No across-the-board standards exist for the cleanup of uranium mine wastes; however, several states and the BLM have guidelines. Prioritization methods generally include a consideration of the severity of physical and environmental hazards associated with a site and the likelihood that receptors will encounter the hazards. Sites close to populated areas (e.g., towns, schools) or attractive features (e.g., recreation areas, historic sites) are generally considered higher priorities than more-remote sites, especially for addressing physical hazards.

Radiological hazards are of greatest concern for mine areas that have the potential for residential use (e.g., tribal or private lands) or that may receive high levels of use by local populations. These hazards are less of a concern for lands most likely to see only occasional recreational use, such as lands managed by the BLM or the U.S. Forest Service. Conversely, physical hazards can pose a serious threat to both frequent and infrequent visitors to a site.

Cost and Feasibility of Reclamation and Remediation

Cost estimates were developed for each production-size category in lieu of estimates for individual mines. A bottom-up cost model was prepared to estimate the cost for performing reclamation and remediation for each size category.

The costs for mine reclamation or remediation vary significantly, and costs for individual mines cannot be estimated without site-specific data. Reclamation typically involves mitigating the physical hazards by closing shafts and adits and stabilizing and covering the waste-rock pile. Remediation often involves taking action to address contaminated groundwater, removing waste-rock piles and other surrounding soils that exceed cleanup levels, and placing the removed material in an onsite or offsite repository. For this Report, remediation cost estimates include activities that would be included in reclamation. The two actions should therefore not be added together.

Reclamation and remediation costs per site in each of the production-size categories ranged as follows:

Tons of Ore Produced	Mine Production-Size Category	Range of Reclamation Costs	Range of Remediation Costs
0–100	Small	$10,000–$70,000	$10,000–$80,000
100–1,000	Small/Medium	$10,000–$80,000	$20,000–$100,000
1,000–10,000	Medium	$50,000–$250,000	$110,000–$840,000
10,000–100,000	Medium/Large	$270,000–$730,000	$2,500,000–$6,500,000
100,000–500,000	Large	$560,000–$1,400,000	$4,900,000–$15,400,000
>500,000	Very Large	Not Estimated	Not Estimated

The high end of the cost range may be underestimated if there are challenging, site-specific construction conditions or if repositories cannot be located near groups of mines or if the material must be transported to a commercial facility. Thus, the cost of an individual mine remediation may be significantly higher than the range presented, as the range depicts a reasonable average for two different scenarios. Costs for Very Large mines were not estimated because they all have either undergone or are undergoing reclamation or remediation.

The costs for performing long-term monitoring and maintenance (LTM&M) were also estimated, based on the assumption that mines would be inspected annually for 10 years and repositories would be inspected annually for 30 years. The annual cost for LTM&M was estimated to range from $2,000 to $6,000 for a mine and $11,000 to $13,000 for a repository.

Remediation/Reclamation Status

To obtain information on the status of mine remediation and reclamation, DOE reviewed federal, tribal, and state records. Mine reclamation is typically conducted by BLM and the U.S. Forest Service under their respective statutory authorities. Cleanup[2] efforts can range in scope from closing a portal as part of mine reclamation to address a safety hazard to a full remediation of contaminants from soil and water and the removal of site structures. All remediation efforts must be consistent with the National Oil and Hazardous Substances Pollution Contingency Plan, and remediation at National Priorities List Superfund sites must comply with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act.

For this Report, categories of remediation and reclamation were defined as remediated, reclaimed, in-process, closed, permitted, not reclaimed, and unknown. Of the 4,225 mines identified, only 15 percent (614) could be confirmed to have had some form of reclamation or remediation completed.

Conclusions

For all the receptor scenarios evaluated, radon was the main contributor to radiological risk. Reclamation that includes stabilizing and covering the waste pile helps mitigate radon and gamma emissions. Sealing adits and shafts can also provide significant reductions in potential radon exposure.

[2] The word "cleanup" is used generically in this Report to include all activities involved in reclamation and remediation of mines.

Defense-Related Uranium Mines

Table of Contents

List of Figures

List of Tables

Acronym List

AEC	U.S. Atomic Energy Commission
AML	abandoned mine land
BLM	U.S. Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FLPMA	Federal Land Policy and Management Act
GAO	U.S. Government Accountability Office
HUC	hydrologic unit code
ICRP	International Commission on Radiation Protection
LTM&M	long-term monitoring and maintenance
mine	abandoned uranium mine
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NPS	U.S. National Park Service
NWIS	National Water Information System
pCi/g	picocuries per gram
Ra-226	radium-226
SMCRA	Surface Mining Control and Reclamation Act
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

I. Legislative Language

The National Defense Authorization Act for Fiscal Year 2013, enacted January 2013, mandated that the U.S. Department of Energy (DOE) prepare a Report to Congress on abandoned uranium mines (mines). Specifically, Section 3151 of the legislation requests, in part:

> The Secretary of Energy, in consultation with the Secretary of the Interior and the Administrator of the Environmental Protection Agency, shall undertake a review of, and prepare a report on, abandoned uranium mines in the United States that provided uranium ore for atomic energy defense activities of the United States.

The Act also requires consultation with other relevant federal agencies, affected tribes and states, and the interested public.

This Report to Congress must be submitted to the following congressional committees no later than July 2014: the Senate Committees on Armed Services and Energy and Natural Resources and the House of Representatives Committees on Armed Services, Energy and Commerce, and Natural Resources. This Report must describe and analyze the following:

- The location of the mines on federal, tribal, state, and private lands based on existing inventories developed by federal agencies, tribes, states, and other available information sources
- The extent to which mines pose or may pose a significant radiation hazard or other public health and safety threat and have caused, or may cause, water or other environmental degradation
- A priority ranking for the reclamation and remediation of the mines
- The potential cost and feasibility of reclamation and remediation in accordance with applicable federal law
- The status of efforts to remediate or reclaim the mines

II. Introduction

DOE used records from the U.S. Atomic Energy Commission (AEC) to develop a list of mining claims that sold uranium ore to AEC from 1947 to 1970 for defense purposes. The AEC records were the most reliable and comprehensive source of data for mines that provided such ore. A total of 75.9 million tons of uranium ore from domestic mines was produced for defense-related purposes during this period.

For purposes of this Report, DOE defined a defense-related mine as being generally associated with a patented or unpatented mining claim (established under the General Mining Law of 1872, as amended) or a lease of federal, tribal, state, or private lands from which all or some of its uranium ore was sold to AEC.[3] Some mines continued to operate after the AEC stopped purchasing, others have been reclaimed or remediated, and a small number are permitted, but may not be operating. Mines in any of these categories are still included in the set of mines evaluated. A mine may be a single feature such as a surface or underground excavation, or it may include an area containing a complex of multiple, interrelated excavations. A mine may include associated features such as mine adits and shafts (mine openings), surface pits and trenches, highwalls, overburden or spoils piles, waste-rock piles, structures, production and ventilation shafts, stockpile pads, mine-water retention basins or treatment ponds, close-spaced development drill holes, trash and debris piles, and onsite roads. For this Report, a mine does not include offsite features such as ore-buying stations, uranium ore transfer stations, or ore used in structures, roads, and general fill. DOE did not interpret the legislation to include these offsite features.

In an effort to develop a comprehensive list of the mines and their condition, DOE compared the AEC production records with those from one tribal nation (Navajo Nation), the U.S. Environmental Protection Agency (EPA), the U.S. Forest Service (USFS), the U.S. National Park Service (NPS), the U.S. Geological Survey (USGS), the U.S. Bureau of Land Management (BLM), the U.S. Bureau of Reclamation, and state agencies that regulate abandoned mine lands (AMLs) to gather the most information available on the individual mines. DOE also solicited input from the public on its Office of Legacy Management website, by email and by hosting webinars, and by participating in and presenting at information exchange forums such as the National Association of Abandoned Mine Land Programs annual conference and other private, state, tribal, and federal mining and abandoned mine land forums. Mine information collated included location, reclamation and remediation status and costs, physical features, and radiological data.

III. Location and Status

The AEC production tables list 4,140 mining records, which include claims, leases, and permits on federal, state, tribal, and private lands. Through review of other agency records containing latitude and longitude coordinates, an additional 85 mines that could be considered defense related were added (all on the Navajo Nation), making a total of 4,225 mines in the DOE mines database. While this figure was calculated from a variety of sources identifying known mine sites to date, this figure is still subject to change since further review of information may add to, or subtract from, the total number of mines. Information from the states, tribes, and federal

[3] Location and other relevant data were provided by numerous agencies including the U.S. Bureau of Land Management, the U.S. Environmental Protection Agency (EPA), the Navajo Nation, and abandoned mine land (AML) programs of states and other federal agencies. The most significant reason for differences in the number of mines reported is that some AML programs count individual mine features (e.g., an adit, a waste rock pile). In addition, EPA's definition of mines can include ore processing facilities. In the case of uranium mines, the mills that processed the ore have been or are being remediated under the Uranium Mill Tailings Radiation Control Act of 1978, as amended.

agencies differs in numbers, generally due to differing definitions of a mine. Some agencies count individual features as mines, as opposed to the complex of features that is used in DOE's definition. Consequently, many other agencies and tribes report more mines than DOE. Limited field visits revealed that there may be multiple mines adjacent to what was recorded in the DOE mines database as only one named mine site. Also, potential duplicates were identified but not excised from the list of mines, as not all information about certain mines is known at this time. Of the 4,225 mines identified, locations were determined by longitude and latitude (but not always verified) for 3,633 mines. Another 566 mines were located by state and county but lack definite latitude and longitude coordinates. No location information was available for 26 mines.

The mines were assigned to production-size categories that ranged from Small (0–100 tons) to Very Large (>500,000 tons) based on the amount of ore sold to AEC. The Small production-size category comprises about 46 percent (1,936) of the total mines identified. Figure 1 shows a graphic representation of the different size categories by showing the equivalent number of trucks necessary to haul that volume of ore. For a common reference, a typical construction dump truck has a hauling capacity of approximately 20 tons.

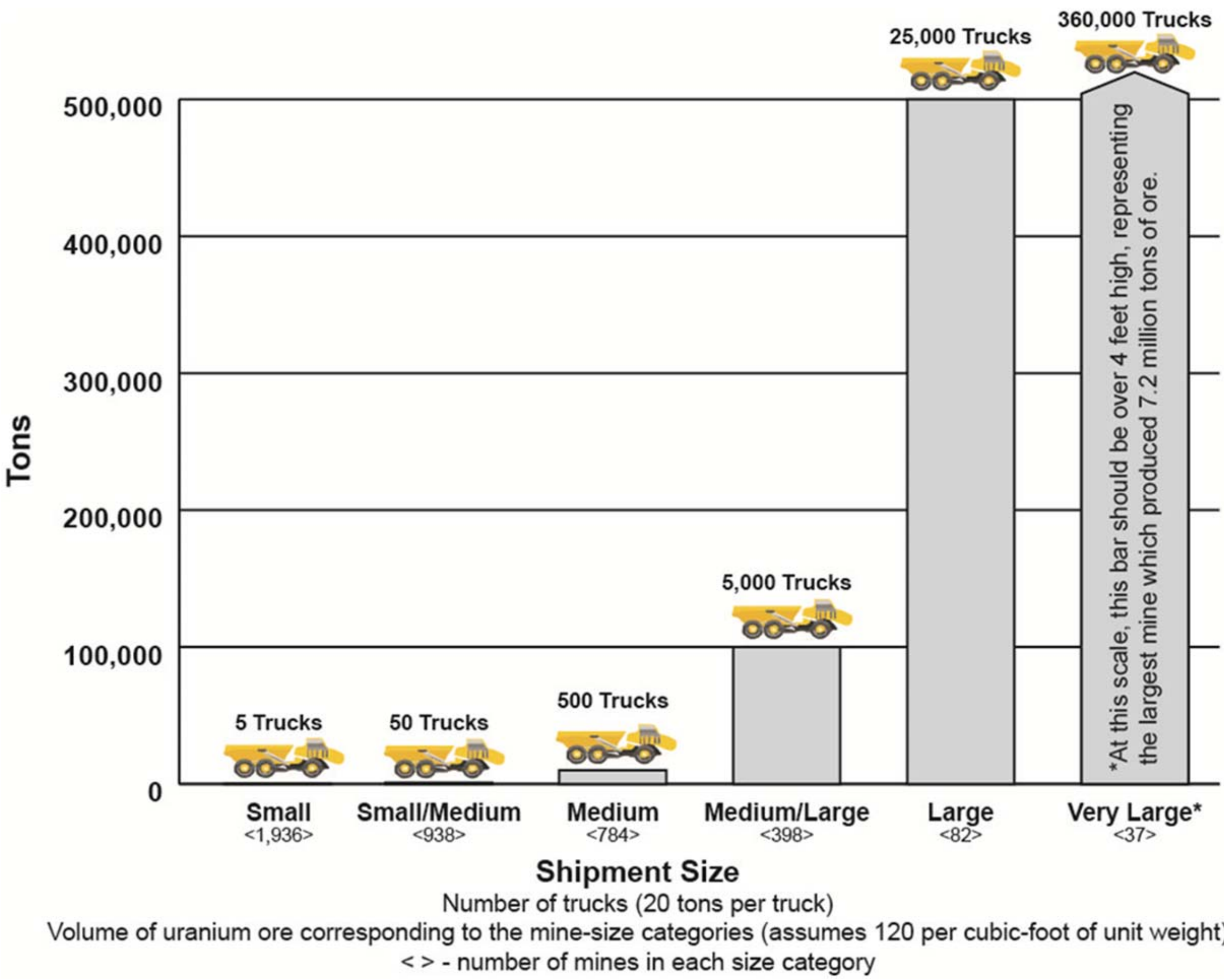

Figure 1. Tons of Ore for Each Production-Size Category

Approximately 69 percent of the mines are in Colorado (1,539) and Utah (1,380), with another 23 percent located in Arizona (413), Wyoming (319), and New Mexico (247). Out of 75.9 million tons of uranium ore produced for defense-related purposes, New Mexico mines produced over 35 million tons, followed by Colorado, Utah, and Wyoming, each with more than 11 million tons. Table 1 is a summary of mine sites by production-size category and state location, and Figure 2 shows the number of mines and production level by state.

Nearly one-half (2,103) of the mines are located on BLM-managed land. A total of 70 percent of mines are on federal and tribal land (453 mines or approximately 11 percent are on tribal lands). The remaining mines are on non-federal and non-Indian land (600, or 14 percent) or land of unknown ownership (657, or 16 percent).

Table 1. Summary of Mine Sites by Production-Size Category and State

State	Total Mines By State	Percent of Total Mines by State	Small Mines	Small/ Medium Mines	Medium Mines	Medium/ Large Mines	Large Mines	Very Large Mines	Mines of Unknown Size
Alaska	1	<0.1%	0	0	0	1	0	0	0
Arizona	413	9.8%	162	110	83	28	4	1	25
California	26	0.6%	21	3	2	0	0	0	0
Colorado	1,539	36.4%	621	378	348	167	22	3	0
Florida	1	<0.1%	1	0	0	0	0	0	0
Idaho	7	0.2%	1	2	4	0	0	0	0
Montana	19	0.4%	10	8	1	0	0	0	0
Nevada	24	0.6%	12	8	3	1	0	0	0
New Jersey	1	<0.1%	1	0	0	0	0	0	0
New Mexico	247	5.8%	78	39	40	33	17	19	21
North Dakota	14	0.3%	2	2	5	3	0	0	2
Oklahoma	2	<0.1%	2	0	0	0	0	0	0
Oregon	4	0.1%	1	0	2	0	1	0	0
Pennsylvania	1	<0.0%	0	1	0	0	0	0	0
South Dakota	155	3.7%	71	35	34	13	2	0	0
Texas	29	0.7%	6	4	8	8	3	0	0
Utah	1,380	32.7%	788	278	190	100	17	5	2
Washington	17	0.4%	0	11	3	2	0	1	0
Wyoming	319	7.6%	135	57	61	42	16	8	0
Unknown Location	26	0.6%	24	2	0	0	0	0	0
Total	4,225	100%	1,936	938	784	398	82	37	50

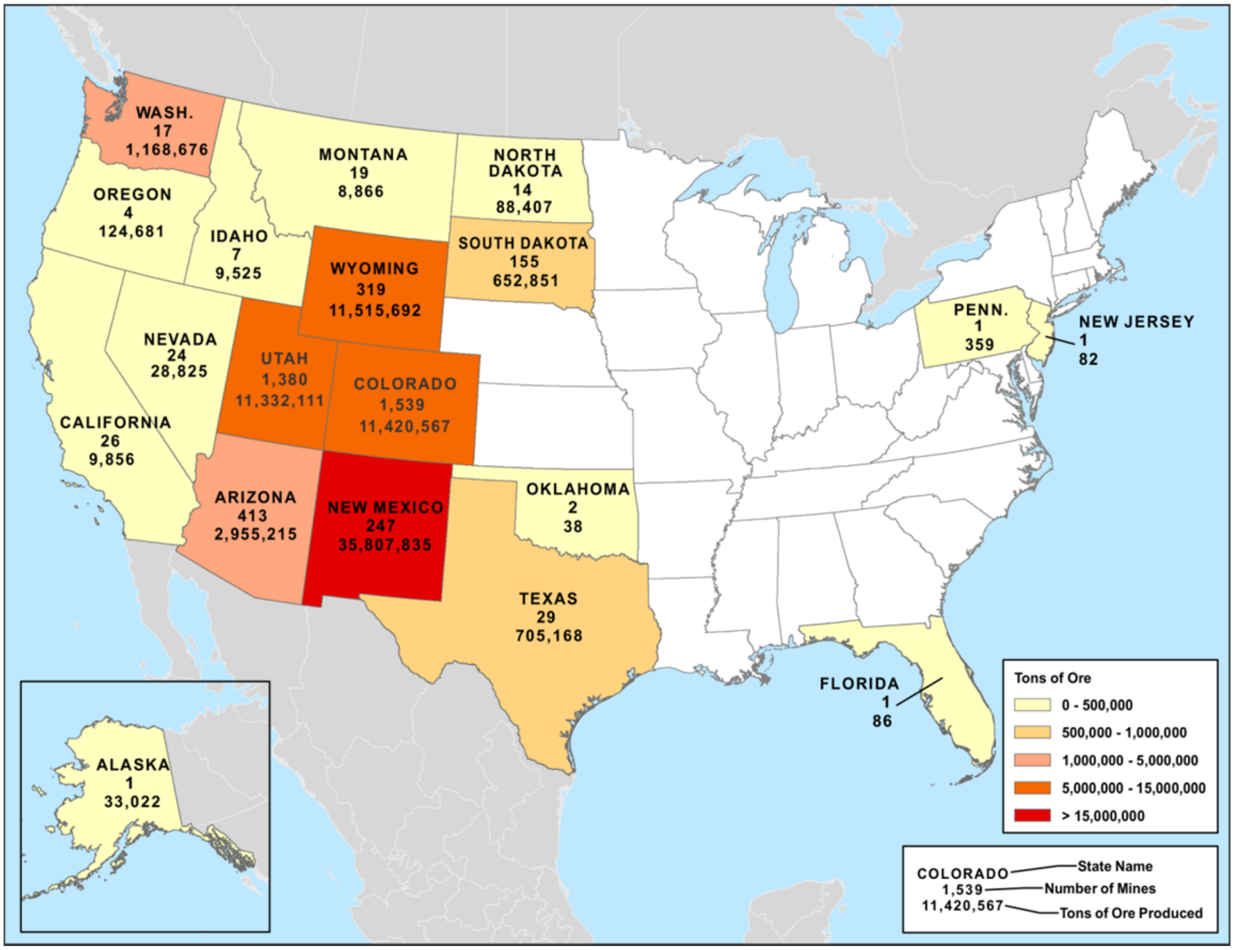

Figure 2. Illustration of Total Uranium Ore Production by State

IV. Assessment of Risk to Human Health and the Environment

The following evaluation was conducted for potential impacts to human health and the environment: (1) potential human health risk from radiation associated with the mines, (2) potential physical hazards, (3) water quality degradation, and (4) potential ecological impacts. Several human health and ecological risk assessments prepared by other federal, tribal, and state agencies for inactive uranium mines were also reviewed to provide perspective on approaches to risk assessments.

Radiological Human Health Risk Conceptual Site Model

Because it was not possible to evaluate each mine, DOE developed an "average" mine for each of five production-size categories to facilitate the generation of input parameters and assumptions used to evaluate the potential for human health exposure to radiation. A sixth category, the Very Large mines, was not evaluated because those mines have been reclaimed or are currently being reclaimed or remediated.

A conceptual site model was developed to identify potential sources of contamination, plausible receptors, and exposure pathways. One conceptual site model was used as the basis of the risk evaluation for the five production-size categories of mines evaluated; although the dimensions would vary with mine-size categories, the relevant components (i.e., source, receptors, and exposure pathways) would be similar. The following potential sources of contamination were considered: waste-rock piles or dumps, potential ground surface contamination (including surface contamination of mine workings or structures), and adits and shafts. The receptors evaluated were an onsite resident (including two scenarios—onsite resident A with a dwelling on top of a waste-rock pile and onsite resident B with a dwelling on the mine site area and with waste-rock material used in the dwelling foundation), an offsite resident, a recreational visitor, an occasional visitor, and a reclamation worker. The scenarios evaluated and the assumptions used were intended to provide perspective by identifying the range of possible exposures. The evaluation considered all plausible receptors including a child as an onsite resident. However, the risk estimates for the adult are higher than a child for all the scenarios.

Potential pathways of exposure evaluated include inhalation of radon and particulates; external gamma; incidental ingestion of soil; and ingestion of plant foods, meat, and milk (for both onsite and offsite resident receptors). The groundwater pathway was not evaluated as groundwater conditions tend to be unique to each mine and should appropriately be done on a site-specific basis. Where groundwater contamination from mines definitely occurs, it could contribute to the overall risk. However, most Small and Small/Medium mines were likely developed above the water table, and many "wet" mines are located in areas where naturally occurring constituents of concern (including radioactive elements) typically associated with uranium mines also naturally occur at high concentrations in the area.

The risk evaluation followed EPA's four components (i.e., data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization) for conducting a risk assessment. The risk estimates were based on an exposure concentration of 70 picocuries per gram (pCi/g) for radium-226 (Ra-226) in the waste-rock pile. DOE acknowledges there is a wide range of Ra-226 concentrations; however, the 70 pCi/g conservatively estimates the risk.

Of the five receptors evaluated (see Figure 3), the risk estimates for the onsite resident (both onsite residents A and B) and reclamation worker risks exceeded 1×10^{-4}. EPA considers a risk range of 10^{-6} to 10^{-4} to be acceptable, and this range was used for comparison. The largest contributor to the risk estimates for all receptors evaluated was inhalation of radon, followed by risks from external gamma radiation from waste-rock piles and contaminated soil. Risks from other pathways (e.g., ingestion of plants, meat, milk, and soil) contributed less than the radon and external radiation pathways.

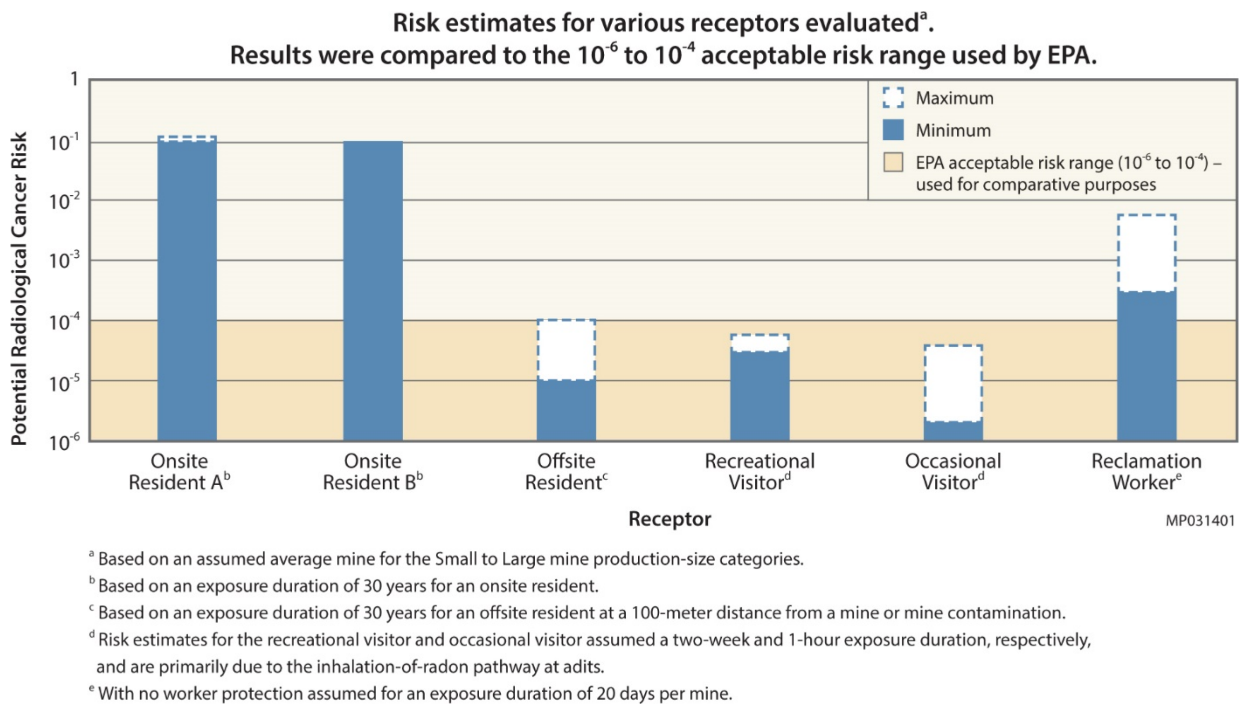

Figure 3. Cancer Risk Estimates for Various Receptors Evaluated

For the onsite resident scenarios, the estimated significant risks would result primarily from the inhalation of radon that emanates from the waste-rock pile or foundation material and diffuses into the house. (EPA calculations have shown that there can be a greater than 10^{-4} risk for people living on a mine or living in contaminated areas near a mine, depending on the level of contamination due to erosion and transport of contaminated soil.) For an offsite resident scenario, risk decreases with distance from the mine. For the recreational visitor, occasional visitor, and reclamation worker, risks were calculated for exposures at mine adits and waste-rock piles. If these receptors spent time at both waste-rock piles and adits, total risks would be additive. Risk reduction through worker protection measures was not taken into account for the reclamation worker calculations, which means that actual worker conditions are expected to be protective in accordance with applicable requirements.

Potential Physical Hazards

In the evaluation of potential physical hazards, all mines that lacked information on location, land ownership, or tonnage produced were excluded, as were mines designated as reclaimed or remediated. The remaining mine locations were evaluated based on (1) distance (within 0.25 mile, within 0.5 mile, etc.) from schools, roads, and population centers and (2) the potential hazards at each site (e.g., open shafts, unsafe structures). The production-size categories of these mines were further sorted into two land ownership categories: federal and tribal/state/private. The majority of mines are on federal public lands (e.g., BLM and USFS).

Of the 3,085 mines evaluated for potential physical hazards, about 72 percent (2,213) have 100 or fewer people living within a 5-mile radius of the mine. Another 24 percent (727) of the mines have between 101 and 1,000 residents living within a 5-mile radius of the mine, leaving only about 4 percent that have more than 1,000 residents within a 5-mile radius of the mine. Fourteen (14) mines have a public school within half a mile of the mine. These results are consistent with the locations of most other abandoned hard-rock mines on public lands. Although physical hazards are associated with all the mine production-size categories, data on the number and type of physical hazards are known for few specific defense-related mines.

Water Quality

Groundwater data is available for only a few uranium mines, primarily ones on the National Priorities List (NPL). For example, mine discharge water from the King Edwards mine in Utah and surface water in some pit lakes (e.g., the Midnite mine, Washington) exceed surface water standards and pose a risk to human health and the environment. EPA reported that 48 mines in the Grants Mining District (New Mexico) operated as wet mines (although some are not defense-related mines), where the underground workings were dewatered to allow mining of ore. Water was pumped from the mines into nearby creeks and drainages resulting in some cases in contamination of the shallow aquifer and underlying bedrock aquifer. However, for some of these mines there is uncertainty about whether there is long-term impact on groundwater quality because of high natural levels of constituents in groundwater of this region that are also associated with uranium mines.

For surface water, the mines were evaluated by comparing their locations with relevant impaired water bodies identified by states and submitted to EPA under the impaired-water-list requirements in section 303(d) of the Clean Water Act (CWA). Impaired water bodies are defined as any surface water bodies (streams, lakes, and reservoirs) that do not meet water quality standards according to their classified water uses. For groundwater, the mine locations were screened against locations in the USGS National Water Information System (NWIS) groundwater quality measurement database with elevated contaminant levels (based on the 4.4 million historical water quality analyses in the database). The screening made use of several criteria, including distance and groundwater concentration information for uranium (and for several metals known to be associated with uranium mines but also associated with other mineral mines and other non-mining activities). This evaluation was done only for comparison; no cause-and-effect relationship between the mines and impaired waters is implied.

There were 169 watersheds with impaired surface water bodies identified in the 19 states with mines, as defined by the USGS 8-digit hydrologic unit code (HUC) for each watershed. There are more than 2,000 USGS-defined 8-digit watersheds in the United States. A comparison of the mine locations with the impaired water bodies indicates that 45 mine locations (about 1 percent of the mines analyzed) are near or immediately upstream from the impaired surface water bodies. Further, these 45 mines are located in only 10 USGS-defined HUC watersheds, with 21 of the 45 mines located in a single watershed.

Similarly, the evaluation of groundwater quality indicated that 44 mines (about 1 percent of the mine sites evaluated) are located within 1 mile of the USGS NWIS measurement sites that have indications of elevated levels of the seven constituents used for screening. These 44 mines are concentrated within 10 USGS-defined HUC watersheds. All 10 of these watersheds occur in areas where other types of mining are prevalent. Therefore, for the groundwater and surface water evaluation, no conclusion can be drawn about the relationship between water impairment and mines. These screening-level results are not to be interpreted as indicating that the mines have impacted or will impact the impaired surface water bodies or degrade groundwater further.

Potential Ecological Impacts

Potential impacts of the mines on ecological resources were evaluated by a review of (1) the radiological risks to ecological receptors exposed to potentially contaminated soils, waste-rock piles, and water and (2) the use of underground mines by bats. This task included a review of ecological risk assessments in reports prepared by other agencies for various inactive uranium mine sites. The task also involved a comparison of (1) the protection levels developed by various agencies and organizations (e.g., the International Commission on Radiation Protection [ICRP]) for ecological species with (2) the radionuclide concentrations used in the human health risk evaluation for this Report.

A review of ecological risk assessments conducted at several inactive mines indicated that both radioactive and chemical contaminants may have a localized adverse impact on biota. However, such results are conservative, in that impacts are generally based on concentrations in waste piles or in onsite drainages, which do not provide optimal habitat. Most concentrations and absorbed doses in waste areas at mines are below recognized protection levels (such as those recommended by DOE and ICRP) for ecological receptors (e.g., no greater than 0.1 rad per day [1 milligray per day] for protection of wildlife). The Ra-226 concentration in waste rock and surface soils (70 pCi/g) assumed for the risk evaluations in this Report exceeds the soil concentration guidelines (50.6 pCi/g). If these guidelines are exceeded at a mine site, more detailed information may be needed to determine whether an actual ecological effect is possible or has occurred.

Many abandoned underground mines have characteristics similar to caves, making them important habitat sites for bats. Therefore, bats are typically the ecological component that influences mine closure and mitigation efforts. A brief review of bat use of abandoned mines was conducted and focused on the beneficial use of mines for bat habitat balanced against potential concerns for public safety. Decisions regarding mine closure should be made in consultation with appropriate experts and need to be weighed against the risk to humans from exposure to radionuclides, particularly radon (Figure 4).

Figure 4. A Mine Adit Closed with a Bat Gate

V. Prioritization of Reclamation and Remediation

In preparing this Report, existing information was collected and reviewed, including:

- Regulatory drivers for the reclamation/remediation of mines
- Regulatory history and status of uranium mine waste
- Standards used for the cleanup of uranium mine sites
- Prioritization criteria for abandoned mines and abandoned uranium mines used by different federal, tribal, state, and local governmental agencies and programs
- Status of mine cleanup by federal, tribal, and state agencies

Mine Regulatory Framework

This Report is not an exhaustive history of AML programs; instead, it provides a framework to better understand the reclamation/remediation of mines. Various federal and state agencies have programs that focus on cleanup of abandoned mines (e.g., BLM AML, Wyoming AML programs); defense-related uranium mines generally represent just a fraction of the total abandoned mine inventory of most agencies. For example, defense-related uranium mines make up only about 5 percent of BLM's total abandoned mine inventory.

In general, mines that provided ore to the AEC operated under provisions of the General Mining Law of 1872, as amended, under which there were no requirements for reclamation or remediation of mines when operation of them ended. As a consequence, many of them were left in an uncontrolled state. Because sale of ore to the AEC ended in 1970, it was prior to the

Federal Land Policy and Management Act (FLPMA) (1976) or to regulations issued by BLM in 1981 requiring mines to be reclaimed when operation ceased. The Uranium Mill Tailings Radiation Control Act of 1978, as amended, enacted near the peak of uranium production in the United States, required EPA in consultation with the Nuclear Regulatory Commission to evaluate the location and potential health, safety, and environmental hazards of uranium mine wastes together with recommendations, if any, for a program to eliminate these hazards. After conducting an analysis of the risks associated with both active and inactive uranium mines, EPA prepared a Report to Congress in 1983; the report made recommendations for regulations to control wastes and air emissions at uranium mines but did not request congressional action for a new remedial action program. In a similar report in 1985, EPA expressed concern that mine wastes may pose a threat to human health and the environment, but that EPA did not have enough information to conclude they do.

From the estimates collected from a number of agencies (e.g., BLM, USFS, NPS), it appears that environmental hazards (i.e., those related to radiological or chemical releases to air and water) are associated with about 10 to 20 percent of the total hard-rock mine inventory. These hazards are generally addressed through Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Clean Water Act (CWA)-based cleanups. Physical hazards are typically associated with as much as 70–80 percent of all hard-rock mines and are the primary focus of the Surface Mining Control and Reclamation Act (SMCRA), FLPMA, and other reclamation-based programs and statutes. Radiological hazards are somewhat unique to uranium mines and may or may not be a factor in mine prioritization. Some agencies consider radiological hazards to be a type of environmental hazard, while others (e.g., NPS) include them as a type of physical hazard. NPS considers any mine with radiation potential as a high priority.

Multiple government entities have conducted, and are conducting, reclamation/remediation of uranium mines under a variety of regulatory authorities and programs. The approach is partly dictated by the goals of the regulatory programs and the mission of the agency. Under the CWA, surface water quality is the highest priority. Under SMCRA, physical safety site hazards are the highest priority; states that have not reclaimed all eligible lands and waters adversely affected by coal-mining practices in their state may use SMCRA AML funds to address non-coal mine sites only in limited circumstances. Any non-coal project in such states must be necessary for “the protection of public health, safety, and property from extreme danger of … mining practices.” If a non-coal site does not pose that level of hazard, AML funds may not be used to address environmental problems at the site. Under FLPMA, the requirement to prevent unnecessary or undue degradation to public lands provides the authority to address both physical safety hazards and environmental reclamation issues at AML sites on federal public lands. CERCLA addresses actual or potential releases of hazardous substances into the environment. CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provides authority for two types of response actions: removal actions and remedial actions. CERCLA responses take into account current and reasonably anticipated future land use. Removal actions (both time-critical and non-time-critical) can be conducted by any federal agency under CERCLA authority granted by Executive Order 12580, and are typically used to mitigate a threat to public health, welfare, or the environment, as well as to increase the pace of CERCLA cleanups. They must comply with provisions of the NCP. Long-term remediation of uranium mine sites listed on the NPL[4] must comply with CERCLA. Agencies conducting cleanups under CERCLA typically prioritize those mines that contribute most significantly to environmental degradation.

There are no across-the-board standards for the cleanup of uranium mine wastes; however, several states and BLM have developed their own guidelines. Site-specific standards are generally developed when needed, based on current and reasonably anticipated future land use. The standards of most state or federal land management agencies are based on background concentrations of site-related contaminants (e.g., radium, arsenic) plus some incremental added risk (e.g., background concentration plus a concentration equal to an added lifetime cancer risk of 1×10^{-4}). Because even fairly low levels of radium can translate into risks above the 1×10^{-6} level for a residential use scenario, CERCLA authority could be used to justify cleanups of mines. If action under CERCLA is deemed necessary at a site, physical hazards may or may not be addressed as part of performing the CERCLA action.

Although the goal of site reclamation is generally focused on removing physical site hazards, closure of mine openings can also reduce or eliminate radiological risks (unless bat gates are installed), depending on the material used to close the openings. The value of reclamation in reducing public exposure to radon emanations at mines has not been well documented.

Prioritization Methods

Prioritization methods generally include a consideration of the severity of physical and environmental hazards associated with a site and the likelihood that receptors will encounter the hazards. Sites close to populated areas (e.g., towns, schools) or attractive features (e.g., recreation areas, historic sites) are generally considered higher priorities than more-remote sites due to the increased risk of exposure to physical hazards. Prioritization methodologies range from simple, single-parameter rankings into “high,” “medium,” and “low” categories to multi-parameter numerical scoring systems. The ability to form joint agency partnerships with multiple funding sources is commonly a consideration in prioritizing cleanups. A recent example of a potential funding source is the proposed Tronox (Anadarko/Kerr-McGee) settlement (April 2014), in which approximately $1 billion may be available for EPA to use to clean up abandoned (formerly Kerr-McGee) uranium mines on the Navajo Nation. Funding for particular mines identified in this proposed settlement may mean that cleanup actions will commence at mine sites that are not considered the highest priority, based on risk, on a national level.

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[4] As of July 22, 2014, three uranium mine sites were listed on the NPL: Fremont National Forest/White King and Lucky Lass Uranium Mines, Jackpile-Paguate Uranium Mine, and Midnite Mine.

DOE did not prioritize mines because each agency and program involved in abandoned mine cleanup already has established priorities based on their particular missions and goals. Nonetheless, based on the risk evaluation, it is clear that mines on lands that may be used for residential purposes (e.g., private and tribal) present the greatest potential risk (after addressing the physical risk). Although some mines on tribal lands may be considered remote (in a relative sense), the potential for residential use would generally make them a higher priority based on considerations of risk and may require a greater amount of cleanup.

For mines on public lands, mine openings pose the most urgent risks—both in terms of physical hazards and radiological exposure due to radon. These hazards can be associated with mines of any size; sites with greater accessibility would pose a greater threat than more-remote locations. Closure and reclamation of mines on public lands can eliminate the most severe physical hazards for recreational users and occasional visitors. Risks posed by waste piles are generally acceptable for the occasional and recreational site users, as well as offsite residents, but can be further reduced by reclamation that includes stabilization and covering the waste rock with clean fill or rock mulch. Agency priorities have generally been established with these factors in mind.

VI. Cost and Feasibility of Mine Reclamation and Remediation

The general approach used to develop the range of costs for reclamation and remediation included collecting and reviewing historical data from other agencies. Costs were not estimated for individual mines. Instead, a cost range for each production-size category was developed using data from site visits to 84 mines in six states and 343 past mine reclamation projects conducted by DOE, including the size and number of mine features.

Developing Cost Estimates

For this Report to Congress, categories of reclamation and remediation were defined as follows:

- **Reclaimed:** Physical hazards are mitigated by closing portals, adits, and vent holes and stabilizing and covering the waste-rock piles.
- **Remediated:** Actions are taken to address contaminated soils, mine-related structures (in some cases), surface water, and groundwater so that the site reaches a risk-based cleanup standard under CERCLA and the NCP.

For this Report, remediation cost estimates should be considered as including reclamation actions. Remediation costs are greater than reclamation costs because remediation generally requires removal of the waste-rock pile and any surrounding soils that exceed cleanup levels and placing the material in an onsite or offsite repository.

Mines may contain numerous features that include adits, shafts, highwalls, trenches, waste-rock piles, roads, impoundments, and structures. Figure 5 depicts the typical physical features and radiological hazards that may be associated with an underground mine.

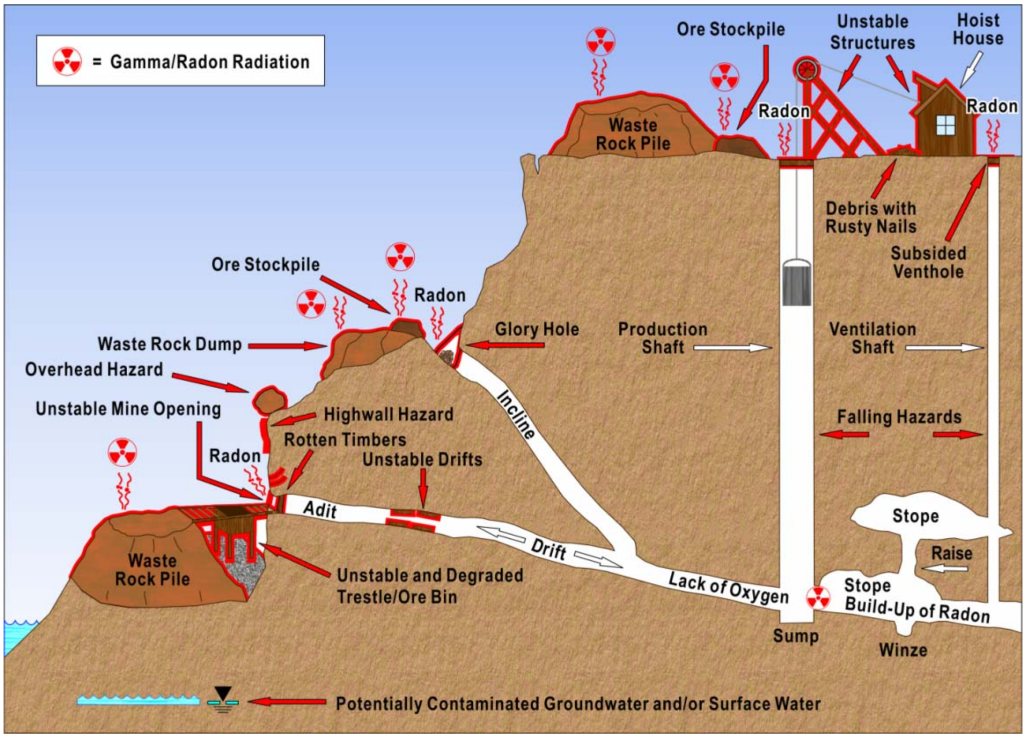

Figure 5. Common Features and Radiological Hazards of Underground Abandoned Uranium Mines

DOE prepared a bottom-up cost model to estimate the cost of performing reclamation and remediation for an average mine in each size category. An average mine was developed conceptually from the 84 site visits and the 343 mines that DOE was involved in reclaiming on lease tracts in the Uranium Leasing Program, and also through a Letter Agreement and an Interagency Agreement for mines on BLM managed lands.

The cost model relied on assumptions that included averaging the number of features for a production size category, estimating the distance to mobilize a contractor, and using established equipment rates from a standardized database. The average wage rate (e.g., U.S. Department of Labor's published wage rates, also known as Davis-Bacon wage rates) for the "Four Corners Region" (including the Navajo Nation) where many mines are located were increased 20 percent because of the recent experience of EPA and DOE in needing to pay higher rates for qualified labor for mine-related work. The costs were compared to historical costs from other agencies to ensure that the estimates were reasonable. Historical cost data, when used, were escalated to current dollars using a published historical cost index. Because of the variable nature of mines, the range of costs per size category is only a preliminary estimate and should not be used to estimate the cost for an individual mine.

The U.S. Government Accountability Office (GAO) and other agencies such as EPA, BLM, DOE, and NPS, have published reports that pertain to hard-rock mines located on public lands. Most of the reports discuss the nature and hazards of abandoned mines and future costs to mitigate the hazards. Except for the GAO reports, the reports analyze all abandoned hard-rock mines, including uranium mines.

Mine Remediation and Reclamation Cost Estimates

Design assumptions were made to provide separate remediation and reclamation estimated cost ranges for each production-size category. Some of the primary factors that varied were (1) mobilization of contractors from different cities, (2) distances to move contaminated material offsite, and (3) the type and complexity of the cover system for a repository. Costs for Very Large mines were not estimated because they all have either undergone or are undergoing reclamation or remediation or have a reclamation bond in place.[5] Table 2 provides estimates of the range of reclamation and remediation costs by mine production-size category. As noted previously, to avoid double counting activity, the two costs should not be combined, but rather should be viewed as an estimated range depending on the strategy chosen for addressing conditions at the site.

Table 2. Mine Reclamation and Remediation Costs per Site in Each Production-Size Category

Tons of Ore Produced	Mine Production-Size Category	Range of Reclamation Costs	Range of Remediation Costs
0–100	Small	\$10,000–\$70,000	\$10,000–\$80,000
100–1,000	Small/Medium	\$10,000–\$80,000	\$20,000–\$100,000
1,000–10,000	Medium	\$50,000–\$250,000	\$110,000–\$840,000
10,000–100,000	Medium/Large	\$270,000–\$730,000	\$2,500,000–\$6,500,000
100,000–500,000	Large	\$560,000–\$1,400,000	\$4,900,000–\$15,400,000
>500,000	Very Large	Not Estimated	Not Estimated

Note: The range of remediation costs includes the cost of reclamation. The two columns should not be added together to get a total cost for reclamation/remediation.

EPA indicated and DOE agrees that the high end of the remediation cost ranges may be underestimated if there are challenging construction conditions or if waste repositories cannot be located near groups of mines or if the material must be transported to a commercial facility. In addition, an individual mine remediation may be significantly higher than the range, due to specific site conditions and recognition that the range depicts a reasonable average for two different scenarios, both of which involve trucking the material 10 miles.

[5] There are mines on Navajo Nation that produced more than 500,000 tons of uranium ore (e.g., Northeast Church Rock mine) but that did not begin operating until after the AEC purchasing program stopped. Therefore, they are not defense-related mines and are not analyzed in this report.

For the Small to Medium size mines, the range of reclamation costs was developed by varying the number of features (e.g., portals, shafts, structures, and vents). For the larger production-size categories, the range of costs was based primarily on varying the size of the waste rock pile and number of structures. Remediation costs were varied based on assuming a large disposal cell and simple cover system that creates an economy of scale (low end of costs) and a smaller disposal cell and more complex cover system that creates the high end of costs.

The costs for performing long-term monitoring and maintenance (LTM&M) were also estimated. Assumptions included inspecting mines annually for 10 years and repositories annually for 30 years. A limited degree of maintenance was assumed, such as replacing eroded cover material used as part of stabilizing the waste-rock piles. If revegetation is part of site stabilization, it can be a challenge in some arid parts of the western United States. Annual costs for LTM&M by mine production-size category ranged from $2,000 to $6,000 for a mine and $11,000 to $13,000 for a repository. The costs to reclaim or remediate a mine vary significantly; without site-specific data, costs for individual mines cannot be estimated.

VII. Remediation or Reclamation Status

To obtain information on the status of mine remediation and reclamation, DOE reviewed numerous sources, including EPA's remediation of mines on Navajo Nation lands; the Navajo Nation AML program; mines undergoing remediation under CERCLA; state AML programs; NPS, BLM, and USFS programs; and the DOE Uranium Leasing Program. Mine reclamation is typically conducted under a variety of organizational guidelines. Consequently, cleanup efforts depend on the intent of the organizations performing the cleanup and vary in scope from simply closing a portal to full remediation of contaminants from land and water and the removal of site structures.

Of the 4,225 mines identified, the reclamation or remediation status of approximately 85 percent (3,575) is unknown. Only 15 percent (614) of the mines could be confirmed to have had some form of reclamation or remediation completed, while only 1 percent (36) had mining permits and are not abandoned.

VIII. Summary and Conclusions

Approach

This Report is a culmination of extensive outreach to, and cooperation with, other federal agencies and with states, tribal nations, and the public. To prepare this Report, it was necessary to rely largely on existing information on defense-related mines. The AEC production records were the most comprehensive and reliable source of information on defense-related mines. The outreach indicates there is significant variability in definitions, level of detail, quality, and completeness among the various data sets relating to abandoned uranium mines. As a result, different data sources might indicate different numbers of mines; however, the difference can be because individual features are sometimes counted as a mine versus part of a mine complex.

The assessments of cost and risk are based on generic, average mine conditions of the 84 mines visited and assessed plus the 343 mines in which DOE was involved with reclamation as part of the Uranium Leasing Program lease tracts and also through agreements for BLM mines. The parameters used to complete the estimates of human health risks and the costs to reclaim or remediate the defense-related mines are intended to be reasonable but conservative and should not necessarily be used to estimate the costs or risk for any individual site.

To understand what progress has been made in addressing mines, it is important to distinguish between "reclamation" and "remediation." In practice, reclamation at abandoned mine sites has often focused on addressing the physical hazards by closing shafts, adits, and vent holes and stabilizing and covering the waste-rock piles. However, environmental issues have also been addressed at abandoned mine sites as part of successfully completing reclamation.

Under CERCLA, remediation is a defined term that means, in substance, taking actions consistent with a permanent remedy to address the release or threat of a release of hazardous substances into the environment. Accordingly, remediation follows the CERCLA process as provided in the NCP to reduce radiation and chemical risk to humans and the environment. Removal actions must also be conducted in accordance with the NCP. Remedial efforts would address contaminated soils and groundwater so that the site reaches a risk-based cleanup standard or a standard that defines protectiveness. Remediation costs can be greater than reclamation costs because, consistent with the purpose of achieving a permanent remedy for the site, necessary remedial action may require removing the waste-rock pile and any surrounding soils that exceed cleanup levels, and placing the removed material in an onsite or offsite repository.

Findings

- Based on a review of AEC records and available data from numerous agencies, there are 4,225 mines that provided uranium ore to the U.S. government for defense-related purposes between 1947 and 1970.

- Mines were grouped by production-size ranging from Small to Very Large. There are 1,936 Small (0–100 tons), 938 Small/Medium (100–1,000 tons), 784 Medium (1,000–10,000 tons), 398 Medium/Large (10,000–100,000 tons), 82 Large (100,000–500,000 tons) and 37 Very Large (>500,000 tons) mines.

- Over 90 percent of the mines are located in five states (Arizona, Colorado, New Mexico, Utah, and Wyoming) and the majority (over 65 percent) of these are Small and Small/Medium mines. However, most of the production in the five states was from Very Large mines in New Mexico. The amount of ore produced in New Mexico alone exceeded that in Colorado, Utah, and Wyoming combined.

- Historically, a primary objective of mine reclamation has been to eliminate physical hazards. At the same time, the value of reclamation in reducing public exposure to radon emanation at mines has not been well documented. After completion of reclamation to mitigate physical hazards and reduce radon emanation, most mines on public lands would have no unacceptable radiological human health risks, given the degree to which total radiological risk is a function of radon exposure. Unreclaimed mines pose the greatest physical hazards, and all mines, regardless of size, can have physical hazards that may pose serious risks.

- The risk calculations for this study indicated that potential risk for two of the five scenarios evaluated (onsite resident [both A and B] and the unprotected reclamation worker) exceed 10^{-4}, which is the upper end of EPA's acceptable risk range. The risk range for onsite residents A and B is up to 10^{-1}, or one in ten. The greatest risk for all receptors is from inhalation of radon—indoor radon for residential receptors and outdoor radon at mine adits or other portals for nonresidential exposures.

- Based on the definition of reclamation and remediation used in this Report, reclamation costs for a given mine size can be less than 20 percent of the cost of remediation for a similar mine size. However, for reclamation and even remediation of mines to remain effective, LTM&M may be necessary. Only a few mines are documented at which LTM&M has been performed for any extended period. CERCLA documents (e.g., Engineering Evaluations/Cost Analyses) project the future cost of LTM&M as part of their life-cycle costs and evaluation of alternatives.

- Existing federal, state, and tribal AML programs or equivalents have established priorities for abandoned mine cleanups (which include uranium mines); consequently, DOE did not establish a separate prioritization scheme. Common to most prioritization methods are risk-based approaches, which include a consideration of physical hazards, environmental hazards (i.e., contaminants), accessibility, and cleanup status. Some agencies consider radiological hazards to be a type of physical hazard from a prioritization standpoint. However, most agencies include radiological contamination as an environmental hazard and consider it separately from physical mine features.

- In their mine reclamation efforts, public land management agencies such as USFS and BLM have put a higher priority on addressing physical hazards than on addressing radiological hazards. This prioritization is based upon the fact that their land is not typically used for residential purposes but rather is used for recreation such as camping limited to a 2-week period.

- Different agencies have made varying levels of progress on reclamation and remediation of abandoned mines in the United States; however, the cleanup status of only 15 percent of defense-related uranium mines could be confirmed. All of the Very Large (over 500,000 tons of ore produced) mines have been or are in the process of being reclaimed or remediated.

- Because of the growing population in the western United States and the increased use of off-road vehicles, many hard-rock mines, including uranium mines, are now considered less remote. Public land management agencies are therefore focusing on prioritizing reclamation of physical hazards at mines that are becoming more accessible.

- Agencies conducting cleanups under CERCLA typically prioritize those mines that contribute most significantly to environmental degradation and pose the greatest risk to human health.

- Some mines are difficult to access because of steep terrain. Establishing access to mines (e.g., construction of roads) for reclamation or remediation has to be balanced by the fact that it makes the mine sites more accessible to the public and may disturb a large area of the environment. These factors would be considered in a CERCLA cleanup during the evaluation of remedial alternatives under the "implementability" criteria in the CERCLA feasibility study and in Engineering Evaluation/Cost Analyses. Implementability is one of nine criteria identified for evaluation of remedial alternatives for CERCLA response actions. In cases where remediation is potentially unsafe or not practical (e.g., steep hillsides), other mitigation efforts may be taken.

- Some mines have impacted groundwater, which can be a significant part of total cleanup cost. Other mines are in areas of high naturally occurring metal constituents in groundwater, including uranium. Some of these mines may have impacted groundwater, but in those instances, the background levels of constituents need to be accounted for in establishing cleanup standards.

- Information provided by EPA noted that many uranium mines in the Grants, New Mexico, Mining District operated as wet mines. Over their years of operation, water was pumped to the surface and discharged into nearby drainages, resulting in significant re-saturation and, in places, contamination of the shallow alluvium and underlying bedrock aquifers. Due to limited time, DOE did not conduct site-specific evaluations of groundwater and surface water. EPA continues groundwater investigations. The Grants Mining District includes some uranium mines that did not produce ore purchased by the AEC (i.e., operated post-1970).

Conclusions

If there is a potential for residential use at a mine site or for living on a contaminated area near a mine (depending on the level of contamination), such as on tribal or private land, the potential human health risks would indicate that remediation and/or implementation of use restrictions may be required. Otherwise, reclamation of all physical hazards may be the preferred approach. For this Report, reclamation that includes stabilizing (particularly if designed to be permanent), covering the waste pile with clean fill, and sealing mine openings where radon emissions can be concentrated, could lower human radiological health risk by reducing radon and gamma exposure. Additional information will better define the scope and size of future cleanup action for mines.