LMS/S10797

Defense-Related Uranium Mines Prioritization Topic Report

Final

June 2014

U.S. DEPARTMENT OF ENERGY | Legacy Management

This page intentionally left blank

LMS/S10797

Defense-Related Uranium Mines Prioritization Topic Report

Final

June 2014

This page intentionally left blank

Contents

Figures

Tables

Appendixes

Abbreviations

AEC	U.S. Atomic Energy Commission
AML	abandoned mine land
AMRP	Abandoned Mine Reclamation Program
ARAR	applicable or relevant and appropriate requirement
BLM	U.S. Bureau of Land Management
Bq/g	becquerels per gram
Bq/m^3	becquerels per cubic meter
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
cm	centimeters
CRCPD	Conference of Radiation Control Program Directors Inc.
CWA	Clean Water Act
DOE	U.S. Department of Energy
DRMS	Division of Reclamation, Mining and Safety
EPA	U.S. Environmental Protection Agency
FY	fiscal year
GAO	U.S. Government Accountability Office (formerly called the General Accounting Office)
GIS	geographic information system
GMD	Grants Mining District
LM	Office of Legacy Management
µg/L	micrograms per liter
µR/h	microroentgens per hour
m	meters
mg/L	milligrams per liter
mrem/yr	millirems per year
mSv/yr	millisieverts per year
NAMLRP	Navajo Abandoned Mine Lands Reclamation Program
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NMAML	New Mexico Abandoned Mine Land (program)

NMED	New Mexico Environment Department
NORM	naturally occurring radioactive material
NPL	National Priorities List
NPS	U.S. National Park Service
NRC	U.S. Nuclear Regulatory Commission
OSM	Office of Surface Mining Reclamation, and Enforcement
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PRP	potentially responsible party
RCRA	Resource Conservation and Recovery Act
SMCRA	Surface Mining Control and Reclamation Act
TENORM	technologically enhanced naturally occurring radioactive material
TMDL	total maximum daily load
UMTRCA	Uranium Mill Tailings Radiation Control Act
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

Executive Summary

The National Defense Authorization Act for Fiscal Year 2013, enacted January 2013, mandates that the U.S. Department of Energy (DOE) prepare a report on abandoned uranium mines. Specifically, Section 3151 of the legislation requests, in part, that “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 states and tribes, and the interested public.

The DOE Office of Legacy Management (LM) defines a defense-related uranium mine (”mine”) as a named mine or complex developed to extract uranium ore for atomic energy defense-related activities of the United States from 1947 to 1970, as verified by purchase of ore by the U.S. Atomic Energy Commission (AEC) or other means. Since the primary basis of the LM mine database is the AEC production records, a mine is generally associated with a patented or unpatented mining claim (established under the General Mining Law of 1872) or a lease of federal, state, tribal, or private lands. By this definition these mines might not be abandoned (some have existing permits) and some mines have been reclaimed or remediated. Mines in any of these categories are included in the set of legacy mines that were considered for evaluation as part of the congressional request for this report. The entire set is labeled as mines and additional information in the four topic reports and final summary report identify the status of these mines.

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, inter-related excavations. A mine may include associated mining-related features such as mine adits and portals, surface pits and trenches, highwalls, overburden or spoils piles, mine-waste rock dumps, structures, 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 impacts or features such as ore-buying stations, ore transfer stations, or ore used in structures, roads, and general fill.

DOE is required to submit a Report to Congress no later than July 2014. That report will describe and analyze:

- The location of mines on federal, state, tribal, and private lands, and the status of efforts to remediate or reclaim these mines
- The extent to which mines pose a significant radiation hazard or other public health and safety threat, and cause, or have caused, water or other environmental degradation
- A priority ranking for the reclamation and remediation of abandoned uranium mines
- The potential cost and feasibility of reclamation and remediation in accordance with federal law

This topic report addresses the priority ranking of mines for reclamation and remediation. It also provides an overview of the regulatory framework for conducting these activities as well as the status of agency efforts to address mines.

Approach

The approach to this topic report included the collection and review of existing information relevant to the following:

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

Results

Few environmental regulations existed at the time the legacy abandoned uranium mine sites were in operation. As a consequence, many of these remain in an uncontrolled state. The need to regulate uranium mine wastes specifically was evaluated in the past as required by the Uranium Mill Tailings Radiation Control Act. A U.S. Environmental Protection Agency (EPA) report to Congress in 1983 made recommendations for regulations to control wastes and air emissions at uranium mines but did not request congressional action. A similar report in 1985 expressed concern that radioactive wastes may pose a threat to human health and the environment, but indicated that the Agency did not have enough information to conclude that they do.

Multiple government entities have conducted reclamation/remediation of uranium mines under a variety of regulatory authorities. The approach to address site hazards and set priorities is partly dictated by the goals of the regulatory programs. Under the Surface Mining Control and Reclamation Act (SMCRA), physical safety site hazards are the highest priority and are generally addressed before any environmental concerns (e.g., contaminant releases to surface water bodies), particularly for mines on public lands. Under Federal Land Policy and Management Act (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 abandoned mine land sites. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), actual or potential releases of hazardous substances are the highest priority. Cleanups conducted under CERCLA are largely based on current and reasonably anticipated future land use.

No set standards exist for the cleanup of uranium mine wastes. Site-specific standards are generally developed when needed based on likely future land use. Most standards are usually based on background concentrations of the site-related contaminants (e.g., radium-226, arsenic) plus some incremental added risk (e.g., background concentration plus a concentration equal to an added lifetime cancer risk of 1×10^{-4}). While the goal of site reclamation is generally focused on removing physical site hazards, closure of mine openings can also reduce or eliminate radiological risks, depending on the material used to block openings. Status and stability are more important indicators of physical site hazards than is size; serious physical hazards can be associated with an unreclaimed mine of any size.

Prioritization methods generally include a consideration of the severity of hazards associated with a site—physical and environmental—and the likelihood that receptors will encounter the hazards. Sites that are close to populated areas (e.g., towns, schools) or attractive features (e.g., recreation areas, historic sites) are generally considered to be higher priorities than sites at remote locations. Prioritization methodologies range from simple 1-parameter rankings into "high," "medium," and "low" categories to complicated multi-parameter numerical scoring systems. The ability to form joint agency partnerships with multiple funding sources is commonly a consideration in prioritizing cleanups.

Major Findings/Conclusions

- A patchwork of regulations is used to address and justify mine reclamation; funding comes from a number of different sources and under numerous legal authorities within several different agencies.
- Uranium mines are usually just a subset of the total abandoned mine inventory that agencies must deal with.
- Different programs use different approaches and cleanup levels, largely based on anticipated future land use. Radiological hazards are of greatest concern for mine areas that have a potential for residential use or that may receive high levels of use by local populations. This hazard is less of a concern for lands most likely to see only occasional recreational use. Conversely, physical hazards can pose a serious threat to both frequent and infrequent visitors to a site.
- Prioritization methods usually consider the severity of environmental hazards (i.e., contamination) and physical hazards and the probability that they may produce adverse effects.
- Most of the mines in the LM mine database are in the smaller size categories. Smaller mines generally are associated with lower radiological risks than larger mines. However, unreclaimed mines of all sizes can have serious physical hazards.
- All organizations have prioritized mines for reclamation/remediation based on criteria that are most relevant to their programs.

This page intentionally left blank

1.0 Introduction and Background

The defense-related uranium mines that are the subject of this topic report are those that produced ore for defense-related purposes, generally between 1947 and 1970. This topic report focuses on two of the requirements for the Report to Congress that is required by the National Defense Authorization Action for Fiscal Year 2013. In accordance with section 3151(a)(2) of that legislation, those two requirements are to:

- Report on the status of any efforts to remediate and reclaim the mines.
- Provide a ranking of priority by category for the remediation and reclamation of the mines.

The major findings from the preparation of this topic report include the following:

- A patchwork of regulations is used to address and justify mine reclamation; funding comes from a number of different sources and under numerous legal authorities with several different agencies.
- For a number of agencies that provided estimates, it appears that water-related hazards (i.e., those related to radiological or chemical releases to groundwater or surface water) are associated with only about 10 percent of their total mine inventory (which includes all hardrock mines). Physical hazards are typically associated with up to 70–80 percent of the inventoried mines.
- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) can address hazardous-substance issues at mines. But for non-coal states (that don't receive Surface Mining Control and Reclamation Act [SMCRA] funds), funding to address non-CERCLA issues (e.g., physical hazards, sedimentation) can be problematic.
- Because even fairly low levels of radium-226 can translate into risks above the 1×10^{-6} excess cancer risk level for a residential use scenario, CERCLA authority could be used to justify cleanups of uranium mines. Once action under CERCLA is deemed necessary, physical hazards can be addressed as well (e.g., U.S. Forest Service cleanup of Rio Blanco County sites in Colorado). However, it would likely be difficult to find potentially responsible parties (PRPs) for the numerous small mines in the mine inventory.
- Whether a mine or group of mines has the potential for joint agency reclamation efforts is often used for prioritization and leveraging of funds.
- Different programs use different approaches and cleanup levels, largely based on anticipated future land use.
- The potential for agency liability might discourage doing less-than-permanent measures (e.g., signage) to address safety hazards at abandoned mine sites.

This topic report first provides a brief history of abandoned mine land (AML) remediation and reclamation history, particularly with respect to environmental laws and regulations. The report then provides a summary of the status of uranium and other AML programs for various agencies and follows with a review of other agency prioritization methods.

This topic report does not provide an exhaustive history of AML programs; instead, it provides a framework into which the reclamation/remediation of defense-related uranium mines can be better understood. While various agencies have programs that focus strictly on abandoned uranium mines, these sites are generally included in broader efforts to address either abandoned mines in general (coal and non-coal) or the combined effects of uranium mining and milling. Therefore, abandoned uranium mines are just a subset of most agencies' broader programs. Federal and state abandoned mine programs are further discussed in Section 3.3. Most of the reclamation/remediation of abandoned mines is driven by environmental laws and regulations. An overview of the most pertinent of these is provided.

2.0 Uranium Mine Regulatory Framework

The General Mining Law of 1872 encouraged the mining of public lands. The vast majority of uranium mines (and mines in general) are located on public lands; nearly half of the uranium mines in the U.S. Department of Energy (DOE) Office of Legacy Management (LM) inventory are on lands managed by the U.S. Department of the Interior's U.S. Bureau of Land Management (BLM) alone. The General Mining Law had no provisions for environmental cleanup. The federal government initiated a program to acquire uranium for defense purposes in the early 1940s.

Few environmental regulations existed at the time that the legacy uranium mines were operational. Though some early laws included provisions for protection of forests or watersheds on public lands, few standards were in place, and enforcement was negligible. The enactment of the National Environmental Policy Act (NEPA) of 1969 and the formation of the U.S. Environmental Protection Agency (EPA) in 1970 signaled the start of significant environmental regulation in the United States. Most of the key environmental laws were passed in the 1970s to early 1980s, and implementing regulations subsequently underwent various modifications and adjustments. Most of the mining-related laws initially focused on the regulation of operating facilities. Operators were required to meet standards for discharges to surface water, air emissions, and hazardous material storage, transport, and disposal, among other activities.

BLM and the U.S. Department of Agriculture's U.S. Forest Service (USFS) promulgated regulations in 1980 and 1974, respectively, requiring mine operators to reclaim areas disturbed by their operations (GAO 1996). Prior to January 1, 1981, however, BLM did not require miners to pay royalty fees or to reclaim mined land. Some operators conducted reclamation under state laws prohibiting the creation of nuisances. However, many mines were abandoned without any reclamation, leaving behind dangerous physical features and **hazardous substances** that could cause environmental damage. (See Appendix A for definitions of terms in **bold.**) While a majority of these mines are on public lands managed by several different land management agencies (such as BLM, USFS, and the National Park Service [NPS]), some patented claims are interspersed, resulting in private lands contained within public boundaries.

Some efforts to address AMLs in general began as early as the 1980s in response to the passage of CERCLA. By the mid- to late-1990s most agencies were beginning to inventory mine sites and get a better understanding of the hazards they posed (BLM/USFS 2007). It was recognized that the mines could pose both physical and environmental hazards. Several agencies began to look at this problem through a "watershed approach," which involves looking beyond individual mines and addressing the collective threat posed by all potential contaminant sources in the affected watershed.

Cleanup of mines sites located on federal lands is the responsibility of the federal agency having jurisdiction over the land, unless those lands become patented and thus private, at which point the states and/or EPA take over cleanup responsibility. The Federal Land Policy and Management Act of 1976 provides direction for lands administered by BLM, and the Organic Administration Act of 1897 (as amended) and the National Forest Management Act of 1976 provide land-management direction for USFS (EPA 2004).

Table 1 lists the major environmental laws that are relevant to abandoned mine cleanup. Table 2 includes major EPA publications that were prepared to provide background regarding the hazards of uranium mine waste and were used to support decisions regarding its potential regulation. Section 2.1 discusses the main laws that are relevant to cleanup of abandoned uranium mines, and Section 2.2 discusses the relevant and major EPA technical reports and summarizes their findings and conclusions.

Table 1. Laws and Regulations Relevant to Abandoned Uranium Mine Cleanup

When	What	Description
1872	General Mining Law	This act declared the public lands free and open to mineral exploration and purchase.
1897	Organic Administration Act	Created the national forest system; includes watershed and forest protection as goals; gives authority to the USFS to take actions within national forest boundaries.
1899	Refuse Act	Prohibited dumping of refuse into navigable waters except by permit; mostly aimed at stopping dumping of materials that impeded navigation (not pollution prevention).
1948	Federal Water Pollution Control Act	First major federal law to address the problems of water pollution; precursor to the Clean Water Act.
1969	National Environmental Policy Act (NEPA) of 1969	The law was established to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and to fulfill the social, economic, and other requirements of present and future generations of Americans. The NEPA process must be followed by federal agencies for actions to be taken on federal lands (e.g., issuing mine permits, reclamation projects).
1970	Clean Air Act (CAA)	Authorizes limits on emissions from industrial and mobile sources. Operating uranium mills are required to meet a radon-222 standard of 20 picocuries per square meter per second ($pCi/m^2/s$), which is the equivalent to 1.9 picocuries per square foot per second ($pCi/ft^2/s$). Underground uranium mine radon-222 emissions must not exceed an effective dose equivalent of 10 millirems per year to a member of the general public.
1972	Clean Water Act (CWA)	Regulates discharges of toxic substances to surface water. Establishes surface water standards. Includes EPA's National Pollutant Discharge Elimination System to regulate discharges to surface water. Radioactive materials are defined as "pollutants."
1974	Safe Drinking Water Act (SDWA)	Ensures the quality of nation's drinking water supply. Under the SDWA, EPA established primary and secondary drinking water standards.
1976	Federal Land Policy and Management Act of 1976	Provides a framework for the management of public lands. Includes a provision to "take any action necessary to prevent unnecessary or undue degradation of the lands." Authorizes BLM to address both physical safety hazards and environmental reclamation issues.
1976	Resource Conservation and Recovery Act (RCRA)	Primary law governing the disposal of solid and hazardous waste; applies to currently operating waste generators.
1976	National Forest Management Act of 1976	The primary statute governing the administration of national forests.
1977	Surface Mining Control and Reclamation Act (SMCRA)	Primary law governing reclamation of coal mines. Established an AML program. After a state's/tribe's coal mines are reclaimed, funding can be used for reclamation of other mines.
1978	RCRA "special waste" exemption	Identified uranium overburden wastes as a "special waste"; exempted it from RCRA storage, treatment, and disposal requirements; and deferred requirements to a future rulemaking.
1978	Uranium Mill Tailings Radiation Control Act (UMTRCA)	Established a program for control/cleanup of uranium mill tailings (milling wastes). Title I includes inactive sites and Title II includes licensed sites. Included a requirement for a Report to Congress on uranium mining waste hazards.

Table 1 (continued). Laws and Regulations Relevant to Abandoned Uranium Mine Cleanup

When	What	Description
1980	Bevill Amendment to RCRA	Created an exclusion from RCRA Subtitle C (hazardous waste) requirements for all wastes from extraction, beneficiation, and processing of metallic ores and overburden from uranium mining; required a Report to Congress on these wastes.
1980	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) of 1986	Law that provided broad federal authority to respond to releases or threatened releases of hazardous substances that could pose a threat to human health or the environment. Established prohibitions and requirements for closed and abandoned waste sites. Provided for liability of persons responsible for releases of hazardous waste.
1983	Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192), "Health And Environmental Protection Standards for Uranium and Thorium Mill Tailings"	EPA finalizes standards for Title I and Title II UMTRCA sites. Title I groundwater standards were subsequently remanded. The radium-226 soil cleanup standards are often used at other sites with radioactive contamination.
1991	RCRA Mining Waste Exclusion Final Rule	All extraction and beneficiation mining wastes exempted from RCRA Subtitle C, but the rule does not exempt these wastes from liability under CERCLA.
1997	40 CFR 192 groundwater standards finalized	Title I groundwater standards finalized for inactive uranium processing sites.

Abbreviations:
CFR = *Code of Federal Regulations*
RCRA = Resource Conservation and Recovery Act
SDWA = Safe Drinking Water Act
UMTRCA = Uranium Mill Tailings Radiation Control Act

Table 2. EPA Reports on Uranium Mine Waste

When	What	Description
1983	EPA Report to Congress	A report on the potential health and environmental hazards of uranium mine wastes 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.
1985	EPA Report to Congress	A report on wastes from the extraction and beneficiation of metallic ores, phosphate rock, asbestos, overburden from uranium mining, and oil shale determined there was not enough information to make a determination of the potential threat of radioactive (uranium mining) wastes; will continue to study.
2000	EPA Report to Congress	EPA submits a report based on a National Academy of Sciences report on guidelines for technologically enhanced naturally occurring radioactive material (TENORM).
2006	EPA TENORM report released	EPA releases vol. 1 of Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining and Uranium Location Database Compilation.
2007	EPA TENORM report released	EPA releases vol. 2 of Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining.

Abbreviation:
TENORM = technologically enhanced naturally occurring radioactive material

2.1 Major Regulations Affecting Reclamation/Remediation of Uranium Mines

Regulations dictate:

- Authority: Who can undertake, oversee, and enforce reclamation and remediation.
- Funding: What sources of funding can be used.
- Cleanup approaches, processes, and priorities.
- Final cleanup goals and waste disposition.

CERCLA recognizes requirements that are chemical-specific, action-specific, and location-specific. This approach to categorizing regulations is useful in viewing laws pertaining to uranium mine reclamation and remediation. Chemical-specific requirements generally pertain to the constituents of concern—that is, which standards apply to particular hazardous substances. Action-specific requirements govern how wastes must be managed and disposed of. Chemical- and action-specific regulations are a focus in this report because they have more general application to all mines. Not considered in this report are location-specific regulations (e.g., the Endangered Species Act) that are applicable only under special circumstances (e.g., where critical habitat for a certain species is present).

2.1.1 Regulation of Uranium-Bearing Materials

Uranium-bearing materials are regulated on the basis of their origin. Uranium **source materials**, **byproduct materials**, and **residual radioactive materials** are regulated by the U.S. Nuclear Regulatory Commission (NRC) under the Atomic Energy Act (See Appendix A for definitions of terms in **bold.**) Uranium mine waste is not considered source material, byproduct material, or residual radioactive material. It is also not considered to be a **hazardous waste** for purposes of regulation under the Resource Conservation and Recovery Act (RCRA). It is considered to be **technologically enhanced naturally occurring radioactive material (TENORM)**, which is not explicitly regulated (although some states are beginning to regulate different forms of TENORM). However, if released into the environment (e.g., in groundwater, surface water, air, or soils), constituents derived from mine waste are considered to be **pollutants** or hazardous substances and may therefore be regulated under CERCLA, the Clean Water Act (CWA), the Clean Air Act (CAA), or other state regulations.

2.1.2 Uranium Mill Tailings Radiation Control Act (UMTRCA)

UMTRCA was passed in 1978 to deal with the potential threat posed by uranium mill tailings. The law was passed near the height of uranium production in the United States (Figure 1) to address both inactive/abandoned uranium processing sites (UMTRCA Title I) and those facilities operating under an NRC license (UMTRCA Title II). EPA was directed to establish standards for residual radioactive material and byproduct material as well as for hazardous constituents in groundwater at Title I and Title II sites. NRC (or the state, in the case of Title II sites in **agreement states**) is the regulator for sites under UMTRCA. LM is the long-term steward for sites requiring long-term surveillance and maintenance activities.

The final rule for Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192), "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," was published in the *Federal Register* in January 1983. These regulations were challenged in court. The soil standards for Title I and Title II sites were upheld. Title I groundwater standards, which were qualitative in nature, were remanded, and EPA was directed to develop Title I groundwater standards that were more in line with those promulgated for Title II sites. Final groundwater standards were published in 1997.

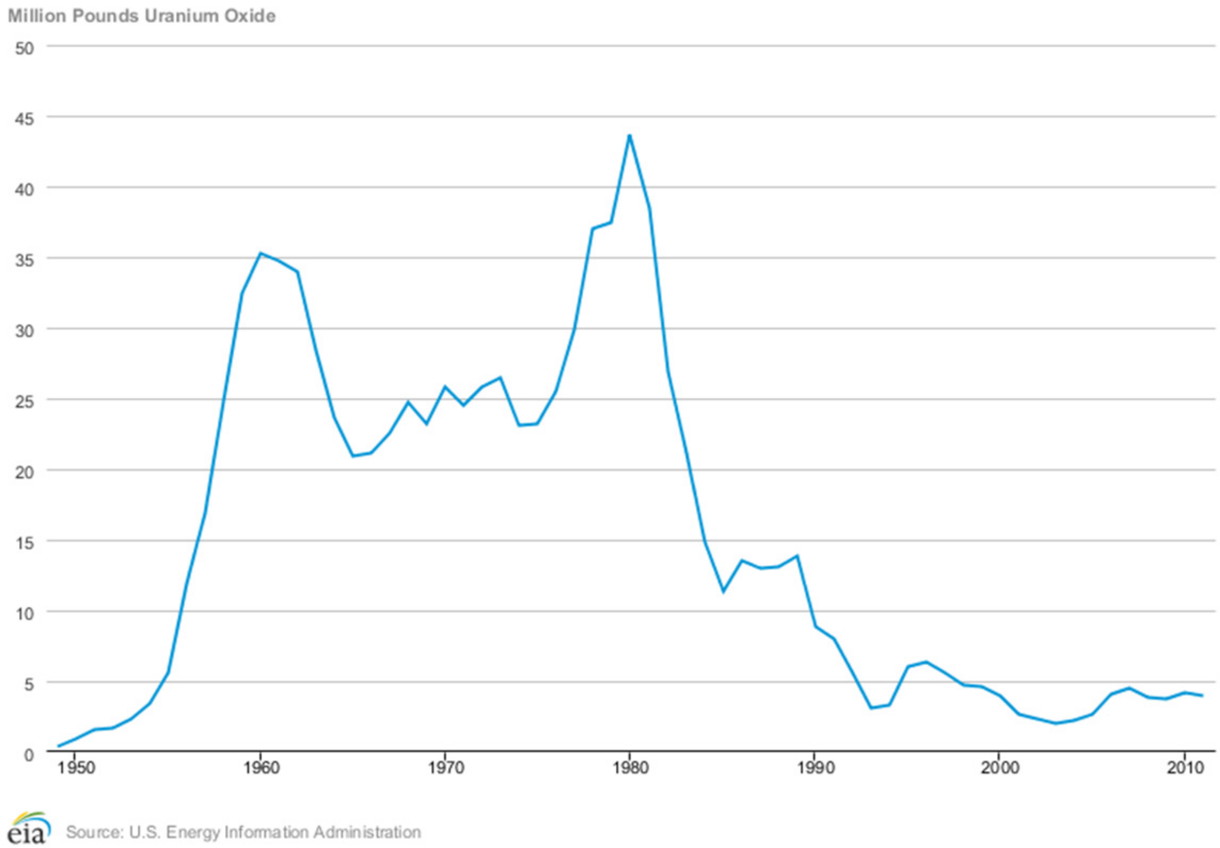


Figure 1. Uranium Domestic Concentrate Production, 1949–2011

The UMTRCA soil standard for cleanup of land at inactive uranium processing sites is as follows: "The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than— (1) 5 pCi/g [picocuries per gram], averaged over the first 15 cm [centimeters] of soil below the surface, and (2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface." (The UMTRCA soil standard described above is sometimes referred to as the **5/15 standard**.) Although there was no standard established for uranium or thorium, the intent was to use **supplemental standards** on a site-specific basis to remediate uranium, thorium, and other radionuclides if present. In conducting cleanups under UMTRCA, a standard was established for internal use by DOE for the cleanup of thorium-230 when it is present with radium-226. The NRC Standard Review Plan for Title I sites (NRC 1993) recommends a standard of 10 pCi/g in the top 15 cm and 30 pCi/g below 15 cm for total uranium.

UMTRCA applies specifically to wastes produced during the "processing" of uranium ores and not to the **extraction** wastes produced during mining. The term "processing" as used in UMTRCA is what EPA would term "**beneficiation**" under RCRA (see Section 2.1.3). The 5/15 radium-226 soil standard (see above) has been used as a radioactive contamination standard by other programs, such as DOE's Formerly Utilized Sites Remedial Action Program. In addition, the 5 pCi/g surface standard was originally proposed as a uranium-mining waste standard under RCRA (EPA 1983), but the standard was not adopted.

At some sites where both mining and milling took place, mining wastes were left unremediated while milling wastes were disposed of as required by UMTRCA. For example, at the Northeast Church Rock mine in New Mexico, milling wastes were temporarily stored at the mine site. During reclamation, uranium/radium ratios were used to distinguish mining from milling wastes; mining wastes were left in place, and milling wastes were placed in a repository—even though total radium-226 contents were very similar, and gamma surveys could not distinguish the two waste types (UNC 1989). (The mine wastes are subsequently being addressed under CERCLA.)

UMTRCA, though focused on uranium-milling sites, directed EPA to examine hazards associated with uranium mining to determine if an UMTRCA-like program was needed to deal with these materials. 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.

2.1.3 Resource Conservation and Recovery Act

RCRA established requirements for the control of solid and hazardous waste. RCRA divides wastes into one of two RCRA categories: Subtitle D (solid waste) and Subtitle C (hazardous waste). Requirements include the land disposal restrictions specified in the 1984 amendments. The disposal requirements and groundwater protection standards in 40 CFR 192 for uranium mill tailings cleanup and disposal were modeled after RCRA regulations. Wastes classified as RCRA hazardous wastes are subject to rigorous treatment, storage, and disposal requirements under RCRA Subtitle C.

The 1978 RCRA Proposed Rule included uranium mining waste rock and overburden as a "special waste" that was presumed to be hazardous. However, not enough information about these wastes was available at that time to set treatment/disposal standards. These special wastes were exempted from storage, treatment, and disposal standards and deferred to later rulemaking until additional analysis could be completed.

In 1980 Congress amended RCRA (through the Bevill Amendment) to exclude all mining waste from regulation under RCRA. It prohibited the regulation of extraction, beneficiation, and **processing** wastes from metallic ores and overburden from uranium mining until a report could be submitted to Congress regarding the hazards of these wastes. As a result of this amendment and the subsequent evaluation, extraction and beneficiation wastes continued to be exempt. However, EPA was required to "tighten" the processing waste exclusions so that only 20 specific processing waste streams were exempt. This did not affect uranium-mining wastes. Extraction (i.e., mining) wastes continue to be excluded from RCRA regulation and beneficiation wastes (e.g., tailings) are regulated under UMTRCA. Note that while uranium mining waste is excluded from RCRA Subtitle C, it is still a solid waste that is subject to regulation under RCRA Subtitle D.

The fact that uranium-mining waste is not a hazardous waste under RCRA means that it is not subject to Subtitle C permitting requirements; therefore, there is more flexibility in designing appropriate disposal methods.

2.1.4 Surface Mining Control and Reclamation Act

Congress passed SMCRA in 1977, which created the Office of Surface Mining Reclamation and Enforcement (OSM) in the U.S. Department of the Interior. Title IV of SMCRA established the Abandoned Mine Land (AML) program. The act provides a major source of funding to coal-mining states and tribes for reclamation of all AMLs. Funds are derived from fees on coal producers. The funds are prioritized for reclamation of coal mines and for the closure of hazardous mine openings in other types of mining operations (EPA 2006a). States and tribes can apply to OSM for certification status once all priority coal mines have been reclaimed. Once a state or tribe is certified, SMCRA funds can be used for reclamation of other mine types (including uranium) or for public facility projects. 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 noncoal mine sites only in limited circumstances. Any noncoal project in such states must be necessary for “the protection of public health, safety, and property from extreme danger of … mining practices.” If a noncoal site does not pose that level of hazard, AML funds may not be used to address environmental problems at the site.

SMCRA establishes high-priority sites as those posing extreme danger, typically due to the presence of hazardous physical features. Hazardous features include irrespirable air and abandoned chemicals/explosives as well as features such as mine openings and highwalls. Medium priority sites are those posing some adverse conditions; lowest priorities are those posing environmental risks. OSM has distributed grants to states and tribes since its inception. Authorized SMCRA states with significant numbers of uranium mines include Colorado, New Mexico, Wyoming, and Utah; the Navajo Nation also has an authorized program. The State of Wyoming and the Navajo Nation have been certified and have directed significant amounts of SMCRA funds toward reclamation of uranium mines.

Two non-SMCRA states—Arizona and South Dakota—contain 9.8 percent and 3.7 percent, respectively, of the number of mines in the LM mine database. These states do not receive SMCRA funding (although the Navajo Nation, with lands within the Arizona borders, does). A report on abandoned mines in California, also a non-SMCRA state, noted the difficulty of securing funding for reclamation of physical hazards (California Department. of Conservation 2000). While sites with environmental hazards being remediated under CERCLA or CWA may also be able to address physical hazards under this authority, sites with only physical hazards may not be considered as urgent. Based on various agency reports, as a rule, physical hazards tend to be far more prevalent than environmental hazards.

2.1.5 Comprehensive Environmental Response Compensation and Liability Act

CERCLA and the Superfund Amendments and Reauthorization Act of 1986 provide broad federal authority to respond to releases or threatened releases of hazardous substances that could pose a threat to human health or the environment. Executive Order 12580 gives all Executive federal departments and agencies CERCLA authority. The law authorizes two types of response actions: (1) short-term removals, where actions may be taken to address releases or threatened releases requiring prompt response, and (2) long-term remedial response actions that permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious but not immediately life-threatening.

The National Priorities List (NPL) is the list of national priorities among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories. The NPL is intended primarily to guide EPA in determining which sites warrant further investigation. Sites placed on the NPL are those that have received a Hazard Ranking System score of at least 28.5. The score takes into account the various pathways for current or potential site releases (e.g., groundwater, surface water, air) and the proximity of receptors/populations that may encounter those releases. Several of the largest uranium mines have been placed on the NPL (e.g., White King/Lucky Lass mine, Midnite mine) and are undergoing long-term response action by EPA. Other smaller, non-NPL mines are being addressed through removal actions (e.g., King Edward mine, Workman Creek Uranium mines).

A PRP is a possible polluter who might eventually be held liable under CERCLA for the contamination or misuse of a particular property or resource. The following four classes of PRPs can be liable for contamination at a Superfund site:

- The current owner or operator of the site
- The owner or operator of a site at the time that disposal of a hazardous substance, pollutant, or contaminant occurred
- A person who arranged for the disposal of a hazardous substance, pollutant, or contaminant at a site
- A person who transported a hazardous substance, pollutant, or contaminant to a site, and who has selected that site for the disposal of the hazardous substances, pollutants, or contaminants

CERCLA provides the federal government with powerful tools to recover costs spent responding to hazardous substance releases, or to avoid such costs by having PRPs perform the appropriate response action or provide upfront funding for such action. It is the policy of some federal agencies (e.g., BLM) conducting cleanups under CERCLA to try to obtain funds from PRPs prior to initiating site cleanups rather than to seek cost recovery after the fact (BLM 2007).

In establishing cleanup objectives for CERCLA cleanups, an analysis of applicable or relevant and appropriate requirements **(ARARs)** must be completed. Potential cleanup standards for use at the site must be identified (e.g., standards established by the CWA or CAA) along with other requirements for conducting site cleanups (e.g., requirements under the Endangered Species Act or the National Historic Preservation Act). If state standards are more stringent than federal standards, the state standards generally apply. If an ARAR cannot be met, it is generally necessary to obtain an ARAR waiver, which is a fairly onerous process. An inability to meet applicable standards is more often an issue with surface water or groundwater contamination than it is with contaminated soils. Because few actual standards have been established for soils (aside from the UMTRCA standard, which is not "applicable" at mine sites, but may be "relevant and appropriate"), a risk-based approach is generally adopted, which can take into account site-specific land uses.

At CERCLA sites, remedial action objectives are typically based on results of a site-specific risk assessment. Risks are usually determined for unrestricted use/unlimited exposure, which typically means a residential use scenario. The acceptable risk range for carcinogenic constituents is 1×10^{-4} to 1×10^{-6} excess cancer risks. (This means that the added lifetime chance of developing cancer due to an individual's site-related exposures are 1 in 10,000 to 1 in 1 million.) Maximum acceptable exposures to noncarcinogenic contaminants should result in a **hazard index** of no more than 1.0. If risks posed by a given site are within or below the acceptable risk range, a response action is generally not warranted (EPA 1991), unless site-specific circumstances indicate otherwise. If a response action is taken under CERCLA, the low end of the risk range is used as a point of departure for evaluating remedial alternatives. To meet unrestricted use/unlimited exposure scenarios, cleanup objectives can often be lower than numerical standards (e.g., drinking water standards) because of the additive effects of multiple contaminants. For less restrictive scenarios (e.g., occasional recreational use), cleanup objectives can be established at higher levels than numerical standards. If unrestricted use/unlimited exposure conditions cannot be met, some type of institutional control is generally required.

The focus of cleanups under CERCLA is on chemical/radiological hazards, in contrast to the emphasis on physical hazards under SMCRA. However, based on site-specific documentation (e.g., Butterfly, Burrell mines; USFS 2011), it appears that remediation undertaken pursuant to CERCLA authority can also address physical site hazards if those hazards are located within the area of CERCLA authority.

Because of the wide scope of liability under CERCLA, including the broad definition of "hazardous substance" and what constitutes a "release," so-called "Good Samaritan" cleanups of abandoned mine sites have been effectively stifled out of fear of being designated a PRP (NAS 1999). Various pieces of legislation have been proposed over more than a decade to try to rectify this, but these efforts at reform appear to have stalled. In the meantime, EPA has issued two memos (EPA 2007b, EPA 2012a) with guidance for Good Samaritan cleanups. These memos better define which parties qualify as Good Samaritans, and the memos provide administrative tools that these non-liable parties can using in cleaning up what EPA refers to as "orphan mines." It is hoped that this clarification will reduce the perceived legal vulnerability for those who want to participate in voluntary cleanup of these sites.

2.1.6 Clean Water Act

The goal of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Title 33 *United States Code* Section 1251(a) [33 U.S.C. 1251(a)]). Under Section 303(d) of the CWA, states and authorized tribes are required to develop lists of "impaired waters" that do not meet water quality standards set by states. The states are required to establish priority rankings for waters on the list and to develop total maximum daily loads (TMDLs) for these waters. TMDLs are the maximum amount of pollutants that a water body can receive and still meet water quality standards.

The CWA requires that states conduct a monitoring program to assess the health of all their waters and report their findings every 2 years to EPA. States use the results of the monitoring to identify point sources and nonpoint sources and their respective TMDLs. If the TMDL analysis identifies nonpoint sources of pollutants as a major cause of impairment, states can apply to EPA for so-called "Section 319 grants." The grants can be used to fund state programs for nonpoint source assessment and control as well as individual projects.

Surface water standards established under the CWA are often considered to be ARARs for CERCLA cleanups. Good Samaritan issues can arise with respect to compliance with CWA requirements, just as with CERCLA. Because uranium mines are generally located in arid climates, effects on surface-water bodies are localized, and CWA requirements are generally not a major driver for uranium mine cleanups. Exceptions may be where a large number of uranium mines occur in a single watershed (e.g., the Cottonwood Wash area in Utah) or where wet mining occurred (e.g., Grants Mining District).

EPA has established effluent limitations for discharges from open pit or underground mines from which uranium, radium, and vanadium ores are produced (40 CFR 440, Subpart C). Limitations are set both for maximum concentrations for any 1 day and for average daily values for 30 consecutive days. For uranium, the maximum effluent limitation is 4 milligrams per liter (mg/L); the 30-day average is 2 mg/L.

2.1.7 Other TENORM Regulations/Standards

In the absence of federal regulations for TENORM (including wastes generated through uranium mining) various organizations have developed guidelines for the use and management of these materials. These may be adopted by states, agencies, or other organizations that deal with TENORM. Two of these guidelines are briefly discussed in this section.

The Conference of Radiation Control Program Directors Inc. (CRCPD) has developed "Suggested State Radiation Regulations Part N: Regulation and Licensing of TENORM" (CRCPD 2004). The suggested regulations include standards for radiation protection of the public and for unrestricted release of sites, among others (e.g., worker protection, recycling). The standard for radiation protection for members of the public indicates that operations at licensed facilities should be conducted such that doses to individual members of the public do not exceed 100 millirems per year (mrem/yr) total effective dose equivalent (TEDE). To qualify for unrestricted use, the concentration of residual TENORM on land must average less than 5 pCi/g of radium-226 + radium-228 above background over an area of 100 square meters.

The American National Standards Institute and the Health Physics Society similarly has developed standards for control and release of TENORM (ANSI/HPS 2009) that applies to practices that use, process, recycle or reuse, and distribute TENORM. The standard it is notes that it may provide suitable guidance to federal or state agencies overseeing remediation projects where TENORM is the contaminant of concern. Standards are provided for the U-238 and Th-232 decay series. Similar to the CRCPD standard, this standard establishes an annual dose limit of 100 mrem/yr TEDE for members of the general public. Outdoor radon at property boundaries of site should not exceed an annual average concentration of 0.5 picocuries per liter (pCi/L). Release levels for volumes of radiologically contaminated materials are set at 3 pCi/g for radium and thorium and associated decay products. The release level for natural uranium isotopes is 30 pCi/g. Criteria are also established for release of surface contaminated materials, indoor radon, and worker protection, among others.

2.1.8 Other Nations' Regulation of Legacy Uranium Mines

The International Atomic Energy Agency was contacted to learn more about any countries with uranium mine cleanup regulations. Canada introduced legislation in 2000 that placed legacy uranium mines under the jurisdiction of the federal nuclear agency. Of main concern for the agency are legacy sites containing uranium mill tailings.[1] Characterization of materials at Canadian legacy sites without uranium mill tailings have generally found that "Under any reasonable circumstance, a member of the public would not receive a dose greater than 10 percent of the public dose limit during 'unstructured' use (<100 h/yr)." The dose limit for the general public in Canada is 100 millirems per year (mrem/yr). Based on the radiological conditions of the legacy mines, it was determined that they could be exempted from licensing requirements. Based on a 2004 status report for these sites, it appears that the mines are tracked and periodically inspected (Canadian Nuclear Safety Commission 2004).

Germany has a Radiation Protection Ordinance of 1 millisievert per year (mSv/yr) (100 mrem/yr) in addition to natural radiation. This dose-equivalent level is used as an action level and remediation goal for protection of the general public and includes outdoor radon. Their "calculation guide" for estimating radiation exposure from mining includes a number of different pathways, including external exposure due to gamma radiation from soil, inhalation of dust, inhalation of radon + daughters, ingestion of breast milk and locally produced foodstuffs, and ingestion of soil. A secondary reference level for cleanup of radionuclides in soils ranges from 0.2 to 1 becquerel per gram (Bq/g) (5 to 25 pCi/g) for each relevant radionuclide; a reference level of 80 becquerels per cubic meter (Bq/m^3) (about 2 picocuries per liter) was established for radon in the free atmosphere. A standard for uranium in drinking water has been established at 10 micrograms per liter (µg/L).

2.2 EPA Reports on Uranium Mine Waste

This section summarizes the results of EPA studies conducted on uranium mine wastes, particularly as they pertain to the current uranium mine evaluation. More details on methodology and results less relevant to this topic report are available in the individual reports mentioned below.

2.2.1 1983 Report to Congress

As a requirement of UMTRCA, EPA was directed to conduct a review of the hazards of uranium mine wastes with the goal of determining whether a program such as UMTRCA was warranted to address the problem of uranium-mining wastes. Congress requested the report at the time when the U.S. production of uranium was at its peak (Figure 1). By the time the report was issued in 1983 (EPA 1983), uranium production in the United States was dropping rapidly.

EPA's evaluation focused on radiological and chemical hazards at both operating and abandoned uranium mine sites. The study was not site-specific but was based on generic models. Physical hazards were outside the scope of the study. The study modeled releases of radioactivity from different sizes of active and inactive mines and looked at potential effects from four routes of exposure: (1) breathing air containing radon daughters; (2) drinking water containing uranium

[1] For the purposes of regulation, legacy mines without tailings are considered to be "contaminated lands" as opposed to "mines." Nonetheless, the sites without tailings have been evaluated to determine if they pose any risks to the environment or the general public.

and its daughters, (3) eating food contaminated by either air or water, and (4) living in homes on land covered by mine wastes.

EPA developed an inventory of active and inactive mines. They looked at characteristics of underground and open-pit mines, including sizes of waste rock piles and excavations. Information from operating mines was used to develop estimates of potential discharges to surface water and emissions to air, as well amounts of solid waste that were generated (i.e., waste piles). Limited field studies were conducted in each state. The compiled information was used to develop “model mines.” Five model mines were evaluated—surface and underground (both active and inactive for each) and in situ leaching.

The model open-pit mines were assumed to be sited in Wyoming; underground mines were assumed to be located in New Mexico. State-specific characteristics (e.g., rainfall and wind, population estimates) were used as input into computer models. EPA used a variety of existing computer codes to estimate doses to individuals and populations (within 50 miles) through each pathway examined. Parameters used in the models were conservative but realistic. Results included estimated doses, estimated cancer risks, and the likelihood of experiencing genetic effects.

Only local water quality problems were identified from uranium mines, but the report cautioned against using this as a general rule and cited the need for site-specific information. It was noted that states may wish to further investigate whether mines are a source of water quality degradation.

The greatest risks were estimated to be from active underground mines due to venting. Surface and inactive mines posed a lesser risk. The greatest risks were determined to be from radionuclide emissions (radon-222 and daughters) inhaled by people living very near the mines. Use of mine waste for building materials can also pose a significant risk (these were not quantified, but were presumed to be comparable to similar exposures to uranium mill tailings).

An individual living for a lifetime 1 mile away from a large, active underground mine was estimated to have an increased cancer risk of 2×10^{-3}, primarily as a result of breathing radon-222. An individual 1 mile away from a large inactive mine was estimated to have an increased cancer risk of 2×10^{-5} to 3×10^{-5}.

An estimated 0.6 additional cancer per year in regional populations around all active and inactive mines was predicted; this is one-third the risk associated with the 24 inactive uranium mill sites (at that time) included under UMTRCA. The risk of genetic effects was estimated to be very small compared to the natural occurrence of hereditary disease.

The report noted that the CWA regulates water discharges, and the CAA regulates air emissions. It was felt that these regulations were adequate for ensuring protectiveness at active mines. The report also noted that mine wastes could contain up to 100 pCi/g of radium-226 and that EPA had proposed listing wastes with radium concentrations greater than 5 pCi/g as “hazardous wastes” under RCRA. However, this designation was pending an EPA Report to Congress on wastes from mines. The report did indicate that EPA could control use of mine wastes as building materials.

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.

2.2.2 1985 Report to Congress

EPA's 1985 Report to Congress (EPA 1985) addressed not only overburden from uranium mining but also wastes from extraction and beneficiation of metallic ores, phosphate rock, asbestos, and oil shale. The objective of the study was to determine whether these wastes should be regulated as hazardous wastes under RCRA. This analysis focused only on extraction and beneficiation (mineral processing wastes were considered separately). The report described potential human health and environmental hazards associated with these wastes. The report expressed concern that radioactive wastes may pose a threat to human health and the environment, but that the Agency did not have enough information to conclude that they do. In the report EPA noted, "We will continue to gather information to determine whether these wastes should be regulated." On July 3, 1986, EPA published the Final Regulatory Determination for Extraction and Beneficiation Waste (Volume 51 *Federal Register* page 24496), which determined that regulation of these wastes under RCRA Subtitle C is not warranted. These wastes continue to be excluded from the definition of hazardous waste.

2.2.3 2000 Report to Congress on TENORM (and a National Academy of Sciences Report on TENORM)

In reports that accompanied the appropriations bills for the U.S. Department of Veterans Affairs, the U.S. Department of Housing and Urban Development, and independent agencies for fiscal years (FYs) 1996 and 1997, Congress requested that EPA arrange for the National Academy of Sciences (NAS) to conduct a study on guidelines for exposures to naturally occurring radioactive material (NORM) (EPA 2000). The committee used the term "technologically enhanced naturally occurring radioactive material" (TENORM) to refer to the materials subject to their study and defined them as follows: "Technologically enhanced naturally occurring radioactive materials are any naturally occurring radioactive materials not subject to regulation under the Atomic Energy Act whose radionuclide concentrations or potential for human exposure have been increased above levels encountered in the natural state by human activities."

The TENORM definition excludes source materials, mill tailings, and radionuclides released to the environment during operations of nuclear fuel-cycle facilities, all of which are regulated by NRC. It does, however, include radioactive materials generated during uranium mining operations, which was recognized as a major source of TENORM. The NAS report (NAS 1999) notes that the average radium-226 concentration in mine overburden is about 25 pCi/g. EPA describes overburden as material "resulting from mining operations and intended for return to the mine site."

EPA asked NAS to examine three major issues:

- Whether the differences in the guidelines for TENORM developed by EPA and other organizations are based upon scientific and technical information or on policy decisions related to risk management.
- If the guidelines developed by EPA and other organizations differ in their scientific and technical bases, what are the relative merits of the different scientific and technical assumptions?
- Whether there is relevant and appropriate scientific information that has not been used in the development of contemporary risk analysis for NORM.

The NAS committee reviewed existing guidelines for all types of NORM and for radiation protection of the general public. They looked at the basis for these and the equivalent in terms of risk in accordance with EPA practice. A summary table comparing risks of these various guidelines was included in the report and is provided in Table 3.

Table 3. Lifetime Cancer Risks Corresponding to Selected Radiation Exposures and EPA Guidances and Regulations for Controlling Exposure of the Public

Risk	Exposure or Guidance or Regulation
4×10^{-2}	Mill tailings standards (cleanup of contaminated land and buildings)
$0.2–3 \times 10^{-2}$	Concentration of radon in homes of 150 Bq/m^3 (EPA; U.S. Department of Health and Human Services [HHS])[a] (4 pCi/L) 1 pCi/L = 37 Bq/m^3
2×10^{-2}	Annual dose equivalent to whole body from external exposure to all controlled sources combined of 5 mSv (existing Federal Radiation Council guidance)
1×10^{-2}	Average annual effective dose equivalent from exposure to natural background radiation, including indoor radon, of 3 mSv (NCRP) (300 mrem)
$0.7–9 \times 10^{-3}$	Average indoor radon concentration of 50 Bq/m^3 (EPA and HHS)[b] (1.35 pCi/L)
4×10^{-3}	Annual effective dose equivalent from all controlled sources combined, excluding indoor radon, of 1 mSv (proposed federal guidance) (100 mrem)
4×10^{-3}	Indoor gamma radiation level of 20 µR/h and indoor residence time of 85%
2×10^{-3}	Concentrations of radium-226 in soil of 0.2 Bq/g in top 15 cm and 0.6 Bq/g below 15 cm and continuous external exposure indoors and outdoors (5/15 pCi/g)
9×10^{-4}	Annual dose equivalent to whole body of 0.25 mSv (25 mrem)
5×10^{-4}	Annual effective dose equivalent of 0.15 mSv (15 mrem)
4×10^{-4}	Annual effective dose equivalent of 0.1 mSv (10 mrem)
2×10^{-4}	Concentration of uranium in drinking water of 20 µg/L
2×10^{-4}	Concentration of radium-226 in drinking water of 0.2 Bq/L (5 pCi/L)
1×10^{-4}	High end of the risk range for cleanup of radioactively contaminated sites (CERCLA and the National Contingency Plan)
1×10^{-4}	Annual effective dose equivalent of 0.04 mSv (proposed drinking-water standard for beta- or gamma-emitting radionuclides) (4 mrem)
1×10^{-4}	Annual dose equivalent to lungs from inhalation of insoluble natural uranium of 0.25 mSv (25 mrem) (uranium fuel-cycle standards)
4×10^{-5}	Annual dose equivalent to bone surfaces from ingestion of soluble natural uranium of 0.25 mSv (25 mrem) (uranium fuel-cycle standards)
3×10^{-8}	Containment requirements for disposal of spent fuel, high-level waste, and transuranic waste (average risk in US population)

Notes:
This table is a modification of Table 7.2 from the National Academy of Sciences (NAS 1999).
Values assume continuous exposure over 70 years and, unless otherwise noted, risk of fatal cancers per unit effective dose equivalent of 5×10^{-5} per millisievert (EPA 1994; NCRP 1993, ICRP 1991).
[a] Lower bound for risk applies to individuals who have never smoked, and upper bound applies to smokers; for former smokers, risk may lie in between.

Abbreviations:
HHS = U.S. Department of Health and Human Services
µR/h = microroentgens per hour
NCRP = National Council on Radiation Protection and Measurements

NAS came to the following conclusions regarding their three issues:

- The committee found that differences in guidelines for TENORM developed by EPA and other organizations are based primarily on differences in policy judgments for risk management and not on differences in scientific or technical information.
- Based on the conclusion to issue 1, issue 2 became moot.
- NAS did not identify substantial scientific information that has not been used in risk analysis of NORM. The committee, did, however, identify research needs that could help in the understanding of TENORM.

It was also noted that different agencies have different purposes and authority for establishing standards. Some standards are established for very specific situations and are not readily transferable to other settings.

NAS indicated that UMTRCA mill tailings standards have been used for cleanups of large volumes of TENORM that cannot be managed as low-level radioactive waste. Examples cited are DOE's Formerly Utilized Sites Remedial Action Program and the Surplus Facilities Management Program.

The committee concluded that differences in standards or guidelines among agencies do not translate into substantial differences in protectiveness or risk. This is partly due to the fact that most guidelines for radiation protection include the principle that exposures of individuals and populations should be as low as reasonably achievable (commonly referred to as ALARA). As a result, actual site cleanups often result in concentrations or doses well below established remediation goals. EPA's Report to Congress summarized the NAS report. Each of the NAS recommendations was identified followed by an EPA response on how they are addressing or planning to address the issue. It was noted in the conclusions that EPA would consult with federal, state, and other organizations as they "progress toward TENORM solutions."

2.2.4 2006/2007 TENORM Reports

As a result of the NAS review of EPA's TENORM guidance, and in light of renewed interest in the uranium industry in the 2000s, EPA undertook a more extensive review of the hazards associated with TENORM from uranium mining. EPA issued a two-volume report in 2006 and 2007. The first volume (EPA 2006b) examined the occurrence of uranium in its natural settings in the United States, its industrial uses, and the methods employed over the last century to extract it from ore deposits. The report also explored the nature of solid and liquid wastes generated by the extraction methods and the various reclamation and remediation methods that can environmentally restore the extraction site.

The second volume (EPA 2007c) examined the potential radiogenic cancer risks from abandoned uranium mines, as well as environmental and geographical issues associated with those mines. The intent of that report was to generally identify who is most likely to be exposed to uranium mine waste and where the greatest risks may be found. While the report acknowledged the physical hazards present at some mines, the focus was on radiological and, to a lesser extent, chemical hazards posed by the mines. Based on reviewer comments received on the draft reports as well as meetings with stakeholders, EPA expected to make a determination on what further steps would be necessary for the purpose of radiation protection from this source of waste material. As part of this effort, EPA also compiled a database of uranium mine locations (EPA 2006c).

EPA defined TENORM as: "Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing." EPA broadened the NAS definition to include materials that have not been modified by human activities but have been disturbed in such ways that they can be misused by humans or can affect the environment. As with the NAS definition, wastes regulated by NRC under the Atomic Energy Act were excluded from the definition of TENORM.

While volume 1 of the EPA report was primarily informational, a few conclusions may be relevant to understanding the current LM mine inventory. These include:

- Surface open-pit mines produce 45 times as much waste, on average, as do underground mines.
- Most older mines (pre- to mid-1970s) were not usually backfilled during or after mining operations.
- The majority of unreclaimed mines may be smaller ones (<25 acres) that would have relatively low reclamation costs.

Work done as part of the current Report to Congress generally supports these conclusions, though no attempt was made to quantify the amount of waste generated from surface versus underground mines.

The primary purpose of volume 2 of the report was to investigate radiogenic cancer risks associated with abandoned uranium mines and to identify who might be most likely to be exposed.

The analysis included both open-pit and underground mines. Risks were determined for nearby residents and for recreationists that might use public lands. The evaluation largely consisted of an update of the risk analysis in EPA's 1983 Report to Congress (risks from radon exposure to a nearby individual and population) and the consideration of additional exposure scenarios. While the focus was on exposures to radionuclides, risks from arsenic exposure were also considered because of its high toxicity and common occurrence in uranium ores.

EPA evaluated four exposure scenarios: onsite recreation, building materials, onsite resident, and nearby resident. It was determined that because the majority of abandoned mines are located on federal lands, the onsite recreational use was the most likely scenario at most mine sites. It was noted that onsite residential use could apply to tribal populations. Soil screening levels were developed for a variety of pathways for different risk levels and exposure frequencies. The soil screening levels provide first-order estimates of cancer risks using conservative assumptions.

Results are summarized as follows:

- Many of the Four Corners states' mines are concentrated in a small number of watersheds.
- In the recreational scenario, short-term exposures to radium, uranium, and arsenic appear to create only minimal additional cancer risk for average concentrations of those constituents. The risk is dominated by external gamma exposure associated with radium.

- Repeated visits to a high-radium/high-gamma site (sub-ore grade) could begin to create a higher risk, even for a recreational scenario.
- The highest risk scenario is that in which mine areas are used for a home site. This scenario could pose a significant cancer risk to a long-term inhabitant.
- It appears that those living on western tribal lands appear to be at most risk as potential residents or from the frequent visiting or passing through contaminated sites.
- Many of the abandoned mine sites occur in areas with low precipitation and deep groundwater so that the risk to drinking-water sources is often low.

The report also provided several considerations for prioritizing sites for cleanup. These include:

- **Depth to groundwater and annual precipitation.** These are considerations for identifying mines that have the greatest potential for environmental damage.
- **Frequency of use.** The location of mines in relationship to roads or other access points will influence how frequently they are likely to be visited, though with all-terrain vehicles and other off-road vehicles, even remote sites can be visited more easily than in the past. Attractiveness may also be a factor.
- **Presence and concentrations of contaminants in soils, water, and sediments.** If contaminant concentrations or waste quantities are low, risks may be inconsequential.
- **Density of mines.** The report notes that while one mine may not pose a problem, a number of mines close together may increase the possibility of presenting human health or environmental effects.
- **Level of acceptable risk.** The report reiterated that EPA's acceptable carcinogenic risk range is 1×10^{-4} to 1×10^{-6} and that the acceptable risk for noncarcinogens is a hazard index of no more than 1.0. It was noted that residential exposures would likely be at the high end of the risk range (or even higher). Because of the location of the majority of mines on federal lands, it was concluded that the most likely exposure would be through recreational use and that this would not typically produce a significant radiation risk. The highest risks may be to residential exposure or use of mine wastes as building materials on the Navajo Nation.

2.3 Remediation Standards

There are no across-the-board standards for the cleanup of uranium mine wastes; however, several states and BLM have developed their own guidelines. A literature survey was completed to identify site-specific and generic remediation standards for uranium mines sites. Approaches range from generic qualitative guidelines that emphasize removal of physical hazards and surface stabilization (e.g., BLM 1992) to site-specific numerical goals established for each contaminant of concern (e.g., Midnite mine; EPA 2006a). Appendix B summarizes the site-specific standards and generic guidance.

As discussed above, CERCLA specifies that remediation goals be established to meet a 1×10^{-4} to 1×10^{-6} incremental lifetime cancer risk. This is reflected in CERCLA guidance for radioactively contaminated soils. CERCLA guidance notes that the 5/15 UMTRCA soil standard (see Section 2.1.2) for radium-226 is generally consistent with the higher end of the CERCLA risk-range if contaminants and their distribution are similar to those found at UMTRCA sites

(EPA 1997b). EPA guidance notes that if a dose assessment is conducted for a site, a 15 mrem/yr effective dose equivalent should be the maximum dose limit for humans (i.e., equal to approximately a 3×10^{-4} increased lifetime cancer risk; EPA 1997b).

Other generic approaches are more qualitative. DOE began reclamation of mines on its uranium lease tracts in the mid-1990s. Because no standards existed for these sites, DOE collaborated with BLM to develop reclamation guidelines (BLM 1995). Numerical goals were not established, but the standard practice was to bury higher-radioactivity material under low-radioactivity or nonradioactive (natural background) material. BLM uses the 5/15 rule as a screening tool for uranium mines, but these levels are not considered to be applicable to uranium mines under a recreational use scenario (based on comment received on the location topic report). Colorado BLM has a goal to "minimize radioactivity emanating from the site." This is accomplished by selective burial of higher-radioactivity material with lower-radioactivity or nonradioactive (natural background) materials. Similarly, the Navajo AML program recognized three classes of materials. Their approach is to bury the most-radioactive materials (>25 pCi/g radium-226) with those of lesser radioactivity (>background but <25 pCi/g) and finish with a cover approaching natural background (around 2 pCi/g).

Most of the site-specific mine cleanups included in Appendix B were conducted under CERCLA. In a number of cases it was noted that background levels of radium-226 exceeded the acceptable risk range. NAS (1999) notes that in a study of uncontaminated (i.e., background) surface soils in the United States, measured values of radium-226 ranged from 0.23 to 4.2 pCi/g. Concentrations of radium-226 in soil corresponding to the 1×10^{-4} to 1×10^{-6} risk range for a residential setting are 1.24 to 0.0124 pCi/g (http://epa-prgs.ornl.gov/radionuclides/). Therefore, even low background values equate to risks greater than the low end of EPA's acceptable risk range. In order to accommodate this, for some sites remediation goals were established as background or as background plus a concentration equal to an acceptable incremental excess risk (e.g., Workman Creek, Juniper mine, Quivira mine). For mines on or near tribal lands, a residential scenario was most often assumed appropriate, and cleanup goals were established that were generally lower than restricted land uses. In situations where a recreational scenario was deemed more appropriate, substantially higher levels were determined to be acceptable. Background levels varied widely among different mine sites reviewed for this report.

Though the examples in Appendix B are dominated by CERCLA-type cleanups, this is not to suggest that the most uranium mine cleanups are designed to meet CERCLA cleanup levels. A substantial number of mines have been reclaimed using the SMCRA approach with more emphasis placed on stabilizing a site and addressing physical hazards than in achieving specific numerical goals. These types of sites tend to be less formally documented and do not show up in a literature review. Large numbers of mines have been reclaimed according to Navajo AML, DOE/BLM, and BLM guidance. Based on EPA Region 9 studies of some of the Navajo sites, further remediation will likely be required before these sites can meet criteria for unrestricted residential use (see additional discussion in Section 3.3.4).

The survey of different cleanup levels and approaches reinforces conclusions drawn by NAS that a variety of guidelines or methods have been used in the absence of standards specific to uranium mines. Final goals vary widely, depending on assumed future land uses. Where residential use is assumed, cleanup goals are driven to lower levels.

3.0 Status of Other Agencies' Prioritization/Reclamation

This section summarizes the progress that has been made over the years to address the reclamation/remediation of uranium mines. The major findings of this evaluation include the following:

- Uranium mines are a subset of the hardrock mines that most federal and state AML programs must address.
- By far the highest doses/greatest risks would be from residential use of mine lands. This scenario is most likely to occur on the Navajo Nation and is being addressed under the Navajo Nation Five-Year Plan process. A major objective of this process is to assess and clean up contaminated structures. Of mines in the largest size category, are all being addressed through an existing program; some are undergoing remediation, and others are just being reclaimed.
- Within the Navajo Nation, 90 percent of uranium mines have been reclaimed; the 10 percent unreclaimed mines are considered to currently be inaccessible. Radiologic hazards associated with the reclaimed mines have undergone a preliminary screening for purposes of prioritization.
- A multiagency effort is underway to better understand the impacts of uranium mining (and milling) in the Grants Mining District. Many of these mines operated as wet mines that resulted in the discharge of significant volumes of water into nearby creeks and arroyos. These historic discharges may be having a continuing impact on groundwater today.
- Federal and state agencies have shifted AML efforts from inventorying to reclaiming/remediating, depending on availability of funds. Sites that pose the most serious threats have generally been identified. However, federal and state agencies and the Navajo Nation face a daunting problem finding funding and resources to remediate the mines.
- BLM has generally prioritized mines based on physical hazards and proximity to populations; less than 6 percent of all BLM AMLs (all hardrock mines) are considered high and medium priority.

Because uranium mines are just a subset of the total abandoned mine inventory that most agencies and states must address, much of this discussion concerns hardrock mines in general. An overview is first provided based on a number of survey reports regarding problems posed by abandoned hardrock mines. A general discussion of prioritization methods is then provided. This is followed by a discussion of AML cleanup programs being conducted by different agencies and states.

Table 4 shows the agencies and entities who own the land that contains most of the mines in the LM mine database. Table 5 shows the six states that have most of the mines in the LM mine database (all other states combined contain only 4 percent of the mines in the database; data were available for Texas so it was also included). The rest of this section provides information on the agencies and states listed in Table 4 and Table 5.

Table 4. Land Ownership of Mines in the LM Mine Database

Owner of Land Where Mines are Located	Percentage of Mines in LM Mine Database	Notes
BLM	49.8%	1% of total mines in the LM mine database are on DOE lease tracts on BLM land
Unknown	15.6%	
State, private, non-federal	14.2%	
U.S. Bureau of Indian Affairs	9.7%	Majority of these are on Navajo Nation land
USFS	8.7%	
NPS	0.7%	Most NPS sites are in Utah

Table 5. States with the Most Mines in the LM Mine Database

Land Ownership/Location	Percentage of Mines in LM Mine Database	Notes
Colorado	36.4%	
Utah	32.7%	
Arizona	9.8%	Non-SMCRA state
Wyoming	7.6%	Extensive numbers of these mines in Wyoming have been addressed with SMCRA funding. Uranium mines inventoried separately from other hardrock mines
New Mexico	5.8%	Separate uranium mine program
South Dakota	3.7%	Non-SMCRA state
Texas	0.7%	SMCRA and State-funded funds were used for uranium mines State funds--$224,000 SMCRA (non-coal): $23,118,000

Note:
[a] Texas data provided during review of prioritization topic report; funding years not specified

In general, agencies first developed inventories and then prioritized the mines in those inventories for reclamation/remediation. Also, reclamation and remediation goals typically reflect the mission of the agency and the regulatory authority being invoked. Mine inventories reviewed for this effort are discussed in the Location/Status topic report.

3.1 General Abandoned Hardrock Mine Overview

General reports on the hazards presented by abandoned hardrock mines have been issued by different government agencies over the years, most notably by the U.S. Government Accountability Office (GAO; formerly called the General Accounting Office). Some of the more notable reports are summarized in Table 6.

Table 6. General Reports on Abandoned Hardrock Mines

When	What	Description
1996	GAO/RCED-96-30	A GAO report on efforts to inventory abandoned hardrock mines, particularly on public lands
1997	*EPA's National Hardrock Mining Framework*	Developed a framework for addressing environmental problems associated with both operating and abandoned hardrock mines; developed with input from numerous stakeholder groups
1998	WGA/NMA[a] Report: *Cleaning Up Abandoned Mines: A Western Partnership*	Provided an overview of western states' efforts to address hazards associated with abandoned hardrock mines
2008	Department of the Interior, Office of the Inspector General Audit Report on AML in the Department of Interior	Report results of an audit conducted on BLM and NPS lands; visited approximately 45 areas and interviewed more than 75 employees from both agencies
2008	GAO-08-574T	Investigated cleanup costs for abandoned hardrock mines compared to financial assurances made by operators
2009	GAO-09-429T	Testimony before U.S. House of Representatives on hardrock mining
2011	GAO-11-834T	Statement on abandoned hardrock mines
2012	GAO-12-544	Investigated potential impacts on the environment of increased uranium exploration and extraction activities on public lands
2013	GAO-13-633T	Testimony; observations on liabilities at hardrock mining sites

Note:
[a] WGA/NMA = Western Governors Association/National Mining Association

The issue of AMLs received more attention after passage of CERCLA in 1980, and it appears that in the mid- to late-1990s there was a greater recognition of the potential risks posed by AMLs. A 1996 GAO report about AML hazards recognized that the hazards were increasing because of the encroachment of development; additionally, the increasing use of all-terrain vehicles no longer made these hazards seem as remote and inaccessible. States and other federal agencies began various efforts to inventory and safeguard their mines (GAO 1996).

EPA and the U.S. Geological Survey (USGS), while not responsible for management of public lands, also started abandoned mine initiatives in the late 1990s. Both agencies are primarily focused on the environmental impacts of abandoned mines. EPA issued *EPA's National Hardrock Mining Framework* (EPA 1997a) to promote a coordinated approach at hardrock mining sites. Some of the largest uranium mine sites have been placed on the NPL (e.g., Midnite mine, White King/Lucky Lass), and EPA has the lead regulatory authority at those sites. EPA is also coordinating the efforts to address human health and environmental impacts of uranium mines on the Navajo Nation and in the Grants Mining District.

USGS had a formal Abandoned Mine Lands initiative from 1997 through 2001. Although the AML program has been concluded, USGS has continued to provide technical expertise in the assessment of contamination associated with abandoned mines and has issued several publications in the last few years that pertain specifically to uranium mines. USGS studied the effects of mines on several watersheds in southeastern Utah to determine potential impacts on sediments and surface water (USGS 2010a, 2010b, 2012). The USGS reports were prepared in cooperation with BLM.

FY 1997 data about state and federal abandoned hardrock mine reclamation activities indicate that the majority of funding came through SMCRA. In many cases this was the sole source of funding. BLM and NPS were funded at levels lower than those of most states, while the USFS received no funding (WGA and NMA 1998). Funding received by the State of Wyoming for non-coal AMLs exceeded funding for all other states and agencies combined (Table 7). Because SMCRA provided a majority of the funds, it is likely that reclamation work focused on physical hazards (assuming sites were prioritized according to SMCRA criteria).

Table 7. State and Federal Funds Spent During FY 1997 for Cleanup of Hardrock AMLs

State/Agency	State Funds	SMCRA (Non-coal)	Total
Arizona	$30,000	–	$30,000
Colorado	$110,000	$1,500,000	$1,610,000
New Mexico	0	$175,000	$175,000
Utah	*	$1,364,000	$1,364,000
Wyoming	0	$22,000,000	$22,000,000
BLM	–	–	$1,000,000
USFS	–	–	$0
NPS	–	–	$45,000
Total**	$2,029,000	$31,100,164	$34,174,164

Notes:
Table modified from information in a Western Governors' Association and National Mining Association report (WGA and NMA 1998).
From 1997 to 1999, Arizona received $30,000 per year for fencing and posting.
Colorado received $110,000 in 1997 from the gaming industry for work around gaming towns.
BLM received $3 million for AML water restoration in FY 1998.
USFS received $4.6 million in FY 1998 plus additional funds for hazardous-waste work.
NPS received $500,000 in AML funding for FY 1998.
*The Utah legislature approved $150,000 for FY 1998.
**The total values do not include EPA CWA Section 319 or Section 104 grants, EPA Regional Geographic Initiative Funds, or Superfund expenditures. Also, according to EPA officials, about 90% of these expenditures are EPA funds, and the other 10% are from PRPs and states.

In the late 1990s most federal agencies were still in the process of inventorying their abandoned mines and estimating the costs to reclaim them (GAO 1996). These inventories were based on different criteria, so that combining inventories was problematic, and no nationwide inventory existed. Initial inventories suggested that only about 10 percent of the mines posed an environmental threat, while a larger proportion were considered to pose physical hazards (GAO 1996). BLM and USFS lands had the highest number of estimated sites. According to estimates, the number of sites on NPS lands was approximately an order of magnitude lower than the number of sites on USFS land. The Federal Mining Dialogue was established in 1995 (BLM/USFS 2007) with the recognition that AML issues cross ownership and regulatory boundaries. At that time it was recognized that working together to establish mutual priorities would avoid duplication of efforts and would maximize the use of scarce fiscal and personnel resources.

A decade later, GAO revisited AMLs on BLM lands to determine what progress had been made. In the same time frame, the Inspector General of the U.S. Department of Interior conducted an audit of BLM and NPS AML lands. According to GAO (GAO 2008), $2.6 billion (in 2008 dollars) were spent on reclamation of abandoned hardrock mines between 1998 and

2007 by four agencies—BLM, USFS, EPA, and OSM (through grants awarded for non-coal projects). EPA had by far the greatest expenditures, likely because they included large and complex cleanup projects, but also because they reflect the emphasis on addressing environmental hazards (Table 8).

Table 8. Expenditures to Clean Up Abandoned Hardrock Mines

State/Agency	FY 1998–2007 Expenditures (Thousands of Dollars)	Percent Total/Rank (States)
Arizona	$927	0.04/31
Colorado	$303,746	12.63/3
New Mexico	$19,194	0.80/20
Texas	$48,860	2.03/13
Utah	$142,133	5.91/5
Wyoming	$102,138	4.25/8
BLM	$50,462	2
USFS	$208,709	8
EPA*	$2,155,916	83
OSM	$198,099	8

Notes:
All dollar amounts are in 2008 constant dollars; percent of total is based on total funding fiscal years 1988 to 2007. Data are from *Hardrock Mining: Information on Abandoned Mines and Value and Coverage of Financial Assurances on BLM Land* (GAO 2008).
*About 90% of these expenditures are EPA's; the other 10% are from PRPs and states.

It was estimated that between 1998 and 2007, BLM inventoried 5,500 sites, remediated physical safety hazards at more than 3,000 sites, and restored water quality at 281 sites through FY 2003 and at more than 3,000 acres since FY 2004 (BLM/USFS 2007). During this same period it was estimated that USFS inventoried 20,000 sites, mitigated more than 2,000 safety hazards, and cleaned up hazardous substances at 400 sites, with 150 more hazardous substance cleanups in progress (BLM/USFS 2007).

Despite these efforts, GAO concluded in 2009 that it was still difficult to obtain good estimates of the number of hardrock mines on BLM and USFS lands (GAO 2009). Using information from the two agencies, GAO estimated that there were 161,111 abandoned hardrock mine sites. They estimated that up to 348,557 hazardous features were associated with these sites, and up to 33,757 of the sites had environmental degradation. It was noted that BLM focused more on identifying sites closer to human habitation and recreational areas than on remote sites (GAO 2009). Table 9 provides GAO's estimate of abandoned mines and features for the states with the greatest number of uranium mines. Again, it should be noted that uranium mines make up only a subset of total hardrock mines. A 2012 Federal Mining Dialogue Summary Paper notes (Federal Mining Dialogue 2012), in response to the GAO testimony (GAO 2009), that agencies in recent years have shifted their focus away from updating their AML inventories to conducting cleanup actions. It was stated that this was in part due to resource limitations, but also because the sites that pose the most serious threats to physical safety or the environment have already been identified.

Table 9. GAO (2009) Summary of Hardrock AMLs for Selected Western States

State	Estimated Number of AML Sites	Estimated Number of Physical Hazards	Estimated Number of Sites with Environmental Degradation
Arizona	50,000	59,400	9,900
Colorado	7,300	17,000	150
New Mexico	800	15,000	200–300
South Dakota	950	Not reported	Not reported
Utah	14,000	14,000	14,000
Wyoming	956	519	437

Notes: Utah figures reflect the State's revised estimate from February 2014

A U.S. Department of the Interior/Office of the Inspector General report focused on hardrock mines in general in three states that do not receive SMCRA funding—California, Nevada, and Arizona. (Of these, only Arizona has significant numbers of uranium mines.) The Inspector General found that significant numbers of hazardous features were still present in areas that were readily accessible. They observed that fencing or signage could provide better warning of some of these features. However, they noted that agency personnel felt that these devices were ineffective and could be costly to maintain. Furthermore, one official indicated that fencing provided an acknowledgement that the agency knew about the site; if an accident or injury subsequently occurred, it was felt that the agency could be subject to increased liability. It was observed that AML programs for both BLM and NPS were not adequately funded and that there was an apparent lack of commitment to the programs.

A recent GAO study focused on uranium mining (GAO 2012). While the main emphasis was on current or planned operations, one component of the study included an examination of abandoned uranium mines and their potential cleanup costs. Data were reviewed from BLM, USFS, EPA, NPS, and LM. GAO concluded that the federal agencies do not have reliable data on the number and location of uranium mines, nor are there reliable cost estimates for their cleanup. The report noted that the mines likely number in the thousands. The report recognized that many agencies are involved in the collection of information regarding abandoned uranium mines, but that the process has been made more difficult because the agencies do not have a standardized definition of what constitutes an abandoned mine site. It was recommended that the agencies work together to standardize a definition for use in data-gathering efforts. Based on discussions with GAO personnel, the agencies are in the process of finalizing internal reviews before formally closing the finding out with the GAO (comment received from USFS on prioritization topic report). Other findings from this report included: (1) agencies' databases are incomplete (e.g., agencies don't track sites after cleanup is complete); (2) agency databases include sites that have not been verified through field inspections; (3) costs for mine cleanup are not known (estimates for individual mines are often based on site-specific conditions). A more coordinated approach to data collection efforts among agencies was recommended. See also GAO's website, for more details (http://www.gao.gov/products/GAO-12-544).

3.2 General Prioritization Discussion

EPA's National Hardrock Mining Framework (EPA 1997a) recognizes that priority setting for reclamation/remediation occurs on a number of different levels—from the national level down to the level of an individual mine. Goals of priority setting on a national level are to determine high-priority states and agencies for targeting resource appropriations. Additionally, the decision must be made whether to target environmental versus safety hazards—these can both be significant, but they generally fall under different legal authorities. On the state/tribal/land management level, the goal of priority setting is generally to identify priority geographic regions that are most severely impaired or threatened by mining activities and to target them for action or near-term evaluation. Prioritization on a watershed level has similar goals but may cross state, agency, and tribal boundaries, such that the potential for forming partnerships is a factor in prioritization. Finally, at a site level, the goal is to identify the individual sources that are most damaging and to determine the appropriate manner to alleviate these impacts.

The multi-level nature of priority setting is somewhat reflected in the various prioritization approaches reviewed for this topic report (and summarized in Table 10), though the majority of methods included are at the agency/state/tribal level. SMCRA prioritization criteria are more qualitative—putting physical hazards ahead of environmental ones. Some of the higher-level prioritization criteria include factors such as the ability to form partnerships for leveraging funding.

Most prioritization methods involve two basic measures: (1) assessing the severity of the hazards present (physical and/or environmental) and (2) assessing the likelihood that these features will impact humans or the environment. Various methodologies involved calculating separate physical and environmental hazard scores and combining these with some measure of accessibility (e.g., distance from a populated area). Most methodologies involve identifying and ranking specific types of hazards and using these to assign scores to individual mines.

Table 10. Prioritization Methodologies

Source	Prioritization Criteria	Notes
SMCRA	**Priority 1**: The protection of public health, safety, general welfare, and property from extreme danger of adverse effects of mineral mining and processing activities. **Priority 2**: The protection of public health, safety, general welfare, and property from adverse effects of mineral mining and processing activities. **Priority 3**: The restoration of land and water resources and the environment previously degraded by the adverse effects of mineral mining and processing practices.	Impacts to groundwater and surface water considered to be of lesser concern unless these pose a threat to public safety.

Table 10 (continued). Prioritization Methodologies

Source	Prioritization Criteria	Notes
BLM Handbook H-3720-1 (2007) BLM Strategic Plan (2006)	Water Quality: • State priority • Partnerships • Cost avoidance/cost recovery • Impairment of water quality standards • Water quality violations • Threat to public health and safety • Continuing/expediting an existing on-the-ground project • Location (on public lands) • Cost efficient Physical Safety Risk Criteria: • Death or injury has occurred • Visitation/high use • Accessibility • Location (BLM lands) • Cost efficient	Up to 10 points assigned for each criterion; result is a numerical ranking. Notes that “water quality sites” follow the CERCLA process for cleanup.
BLM Feasibility Study (2011)	**High priority**: Populated place or school within 0.25 mile of one or more AML sites **Medium priority**: Mining towns, historic schools, recreation areas, parks, camps or trails within 0.25 mile of one or more AML sites **Low Priority:** Sites located more than 0.25 mile away from a populated place	Emphasis in this report was on physical safety hazards only.
National Park Service (2013)	Hazard ratings based on physical features (examples of features are listed): • High Priority—serious or fatal injuries are possible • Medium Priority—moderate injury could occur • Low priority—minimal injury possible Resource impacts rating: • High Priority—Highly elevated contaminants or altered pH; high visual impacts • Medium priority—moderately elevated contaminants or pH; moderate visual impacts • Low priority—minimal contaminants or pH alteration; minimal visual impact	Results in a numerical ranking in 4 categories (hazard, access, resource significance, resource impacts); assigned to a H,M,L priority in each category; extent of workings considered but don’t factor into rankings or priorities. Accessibility not used as criterion to prioritize as H,M,L; considered when deciding which projects to implement. Natural and cultural resource significance not considered in H,M,L prioritization. Radiation potential automatically assigned a 3 out of 5 hazard ranking, and assigned to high-priority group.
New Mexico Mining and Minerals Division (Brancard 2009)	• Radiological hazards • Physical safety hazards • Proximity to homes • Proximity to domestic wells • Proximity to water drainages	Information from a workshop presentation. They have apparently adopted the geographic information system (GIS)-based model methodology of DeLay et al. Result is assignment of a score of 1 (high) to 4 (low).

Table 10 (continued). Prioritization Methodologies

Source	Prioritization Criteria	Notes
A 2009 paper on using a GIS-based model to prioritize uranium mines (DeLay et al. 2009)	Each mine scored on five separate variables: • Number of mine hazards • Radiation measurements • Distance to nearest well • Distance to and clustering of nearest drainage • Number and clustering of dwellings within 5-mile radius	Each variable assigned a rank of 1 (high) to 4; ranks for variable combined for a final priority score of 1 (high) through 4. It is noted that decisions for reclamation need to be further based on site accessibility, land ownership, and proximity to other mines, which could result in a reprioritization for purposes of implementing remedies.
Navajo Nation Priority Mine Cleanups, EPA Region 9 (from January 2013 San Francisco meeting between DOE and EPA Region 9)	Use combination of proximity and gamma above background: • Within 200 feet of potentially occupied structure • Within 0.25 mile of potentially occupied structure • Gamma > 2× background • Gamma > 10× background	
Navajo Nation Atlas Scoring (EPA 2007a)	• Proximity of structure (within 200 feet; 0.25 mile; 1 mile) • Proximity of wells (0.25 mile; 1 mile; 4 mile) • Proximity to perennial or intermittent surface waterway (1 mile, 4 miles, 15 miles)	Different weights assigned to each distance category. Also weighted for the number of structures present. Scores computed for air, soil, groundwater, and surface water pathways; added together for a composite score.
EPA TENORM Report vol. 2 (2007c) (suggests criteria for prioritization)	• Depth to groundwater; precipitation rates • Frequency of use • Presence of contaminants in environmental media • Density of mines • Level of acceptable risk (dependent largely on land use and potential exposures)	Suggests that for environmental concerns (transport of contaminants from mines), uranium may be a more important contaminant than radium-226.

Abbreviations:
GIS = geographic information system

3.3 Agency/State Summaries

This information was assembled using publications prepared by various agencies, background from GAO and other reports, and a summary paper prepared by the Federal Mining Dialogue (2012). This discussion is not intended to make judgments about any agency; rather, the intent is only to provide as comprehensive a picture as possible regarding the status of uranium mine reclamation across the various entities. The discussion is organized according to the lands with the greatest numbers of mines contained in the LM mine database (Table 4).

3.3.1 U.S. Bureau of Land Management

The AML program for BLM addresses all hardrock mine sites abandoned prior to January 1, 1981, the effective date of BLM's surface management regulations (BLM/USFS 2007). Prior to 1981, mining operators were not required to provide a financial guarantee or to reclaim land disturbed by their activities (GAO 2009). The BLM defines hardrock as non-coal mining environments where environmental impacts such as acid-mine drainage, heavy metal contamination, and threats to water quality and the environment are of concern. Hardrock minerals include, but are not limited to, gold, silver, copper, lead, zinc, magnesium, nickel, molybdenum, tungsten, uranium, and selected other minerals (BLM 2013a). Consequently, there are large numbers of AMLs on BLM land. The BLM's AML efforts began with inventory activities in the early 1990s in an effort to quantify the problem and formulate funding requests (BLM/USFS 2007). The initial estimate of abandoned mines on BLM land was 65,000 sites. The BLM AML program was formally established in 1997 in tandem with that of the USFS. The AML program is funded annually through the Management of Lands and Resources fund. The BLM partners with other federal agencies, state agencies, local governments, and private and not-for-profit organizations to collaborate on actions and to leverage vital financial resources. Some of these works partners receive funding through SMCRA, CERCLA, and the CWA Grant Program.

As of January 10, 2013, BLM's inventory included an estimated 39,000 sites and 76,600 features. Approximately 23 percent of the sites either have been remediated, have reclamation actions planned or underway, or do not require further action. The remaining 77 percent require further investigation or remediation (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands.html, accessed October 31, 2013). [Note: This discussion is based on the BLM's usage of the term "remediation" which may or may not be the same as the definition used in the abandoned mine topic reports.] Between 2000 and 2013, the AML program remediated an estimated 7,100 physical safety features and 600 AML sites containing environmental issues, and more than 1,000 acres of water quality were restored (BLM 2013b). The Cottonwood Wash in southeastern Utah, a watershed project jointly undertaken by BLM and USFS, contains numerous remediated mines (BLM 2007).

According to BLM's AML program strategic plan (BLM 2006), it was estimated that most of the sites in BLM's inventory were 5 to 10 acres in size and "conventional" in complexity and impact. It was noted that the higher-risk sites were likely to be those where the public was encouraged to visit (e.g., a recreation area) as opposed to more remote public lands. Consequently, BLM's prioritization criteria (particularly for physical hazards) depend on the likelihood that an area is to be visited or used.

The 2006 BLM AML Strategic Plan contains a compilation of state office work plans that cover prioritized program activities from FY 2007 to FY 2013 (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands/AML_Publications/national_aml_strategic.html). The state work plans identified both physical safety hazard and watershed project priorities. The plans were used to better understand the status of the overall BLM program. Table 11 summarizes the AML hazards reported in selected state work plans.

Table 11. Summary of Hazards from BLM State Hardrock AML Work Plans for FY 2007–2013

State	Total Mine Sites	Physical Hazards	Water Hazards	Notes
Arizona	1,953	961	38	Current inventory focused on major population centers
California	13,000	3,000	1,000	
Colorado	2,751 sites	10,818 features	4,670 features	Only 5–10% of mines have offsite impacts
New Mexico	600	200	none	
Oregon/Washington	133	50	21	
Utah	8,000–17,000[a] features	7,600–15,300	400–1,700	Working with USGS to determine uranium/vanadium mine impacts on water quality
Wyoming	Uranium mines not included in BLM strategic plan; addressed separately in a joint effort with State AML program and DOE according to the strategic plan			

Notes:
Information in this table is from BLM 2006.
Each state's estimate of hazards may be derived through different means so may not be comparable.
Utah figures revised based on BLM estimates at the time of this report. State of Utah reports an estimate of 14,000 features statewide (revised downward from 17,000 previously).

The BLM's AML database contains roughly 2,000 U.S. Atomic Energy Commission uranium mines that are located on BLM managed lands. This is just a small fraction of BLM's estimated 39,000 total hardrock mine sites. The data in Table 11 indicate that water hazards are less prevalent than physical hazards at mine sites. Only about 10 to 20 percent of mines are likely to have significant environmental impacts on water. This figure may be lower for uranium mines, which are typically in more arid locations and less subject to the acid mine drainage found at other hardrock mines. (Note, however, that uranium mines could have radiological hazards that are not present for other hardrock mines.) Few of the priority mines identified in the state work plans were uranium mines (BLM 2006). Based on location information it appeared that several of the priority physical safety sites in Utah were associated with uranium mining. The Utah AML work plan noted that some of the uranium mine areas were being evaluated through studies conducted with the USGS to better understand water-related impacts (BLM 2006).

The BLM has policy guidelines for reclamation of physical hazard and water hazard sites (BLM 2007). The BLM uses NEPA to examine environmental impacts for remediation activities to address physical safety hazard features, and uses its CERCLA authority at sites associated with the release or the threat of release of hazardous substances. The CERCLA process includes conducting a search for PRPs to pay or recover costs for remediation activities. While BLM uses CERCLA authority for water quality sites, it is not clear if this approach is extended to radiation sites (as they present more than just physical hazards). Physical safety hazards can be addressed concurrently with environmental remediation under CERCLA.

BLM's draft guidelines for reclamation of radionuclides (BLM 2001) at mine sites adopt the UMTRCA radium-226 standards of 5 pCi/g above background at the surface and 15 pCi/g with depth. A soil cover of not less than 6 inches is recommended, with 18 to 24 inches of cover preferred. It is not known if these guidelines have been finalized. It appears that the guidance is intended for current mine operators; it is not clear if it applies equally for reclamation of abandoned mines.

BLM has two sets of prioritization criteria—one for physical hazards and one for environmental sites. Highest priority environmental sites are generally those contributing to contamination of a watershed that is considered to be impaired under the CWA and is thus a priority for multiple agencies. A major component of the prioritization for physical hazard sites is accessibility and location with respect to populated areas, recreation sites, or other "attractive" locations. Sites are scored according to these criteria and assigned numerical values for ranking (BLM 2013a).

BLM's recent feasibility study for AML inventory, validation, and physical safety closures (2013c) was created to estimate the costs to validate and address unremediated AML sites posing physical safety hazards. The methodology to rank funding priorities as high, medium, or low was by the proximity to populated places. High priority sites are those within a quarter mile of a populated place or school. Medium priority sites are within a quarter mile of historic mining towns, historic schools, recreation areas, parks, camps, or trails. Low priority sites are those located greater than a quarter mile from a populated area. The study was completed using 2011 data from the AML inventory and there were 22,104 physical safety hazards in the database at that time. The BLM reported that only 2.7 percent of sites in the study (594) were considered to be high priority, 2.9 percent (647 sites) were medium priority, and 20,863 sites were low-priority (BLM 2013c).

3.3.2 DOE Lease Tracts

LM manages a uranium leasing program on 31 lease tracts under the authority of the Atomic Energy Act. These lease tracts are located within the Uravan Mineral Belt of Colorado and were withdrawn by BLM from the public domain in 1948. These sites are therefore a subset of BLM sites from a land-ownership perspective. DOE undertook the task of reclaiming uranium mines on these lease tracts starting in 1994. Because no guidance existed for reclamation of these sites, DOE worked with BLM offices in Colorado to develop reclamation criteria specifically tailored to uranium mine sites. The guidelines call for minimizing radiation emanating from a site by burying higher-radioactive material under lower or nonradioactive (background) material where practical. Particular attention is paid to burial of remnants of ore piles, ore spillage around loadout areas, and higher-radioactive material from mine rock dumps. These guidelines were issued as a supplement to BLM's *Solid Minerals Reclamation Handbook*, H-3042-1 (BLM 1995). Approximately 90 percent of the individual mines on DOE's lease tracts had been reclaimed according to these guidelines as of 2010. DOE conducted reclamation of more than 100 additional mines on BLM land in Colorado from 2000 through 2008.

3.3.3 U.S. Forest Service

USFS began to inventory abandoned mines on its lands as early as at least the early 1990s (USFS 1995). Early cleanups were conducted primarily under USFS's CERCLA authority. USFS started a formal AML program in 1997 to remedy physical and environmental hazards. It manages and mitigates impacts of abandoned mine operations through its Environmental Compliance and Protection/Abandoned Mine Land Program. Approximately 75 to 85 percent of the program's total budget is expended on the cleanup and safety hazard mitigation at abandoned mine sites (Holtrop 2011). USFS estimates that between 18,000 and 26,000 abandoned hardrock mines are on USFS lands. Based on mineral production data for these mines, it is estimated that

9,000 to 13,000 of these mines will likely require environmental cleanup or safety mitigation work. It was estimated that about 20 percent of abandoned mines could harm surface resources (USFS 2004). Since 1998, USFS has mitigated more than 2,000 safety hazards and cleaned up hazardous substances at more than 400 sites; 150 more hazardous substance cleanups are in progress (Holtrop 2011).

Three categories of work may be undertaken at USFS AML sites: (1) hazardous substance cleanup under CERCLA; (2) cleanup of nonhazardous surface disturbances such as revegetation and reconstruction of stream channels and floodplains; and (3) mitigation of physical safety hazards (Federal Mining Dialogue 2012). Mines generally fall into one of three categories: (1) large and complex mine and mill sites in heavily impacted watersheds; (2) drainages affected by historical placer mining; and (3) small mine cleanups and safety hazards. Most of the uranium mines probably are in the third category.

USFS policy requires that a PRP search be performed before spending appropriated funds on CERCLA cleanups (BLM/USFS 2007). However, very few of these searches have resulted in the identification of a viable responsible party, mostly because the mines date back to the 1800s through the early 1900s. Since the legacy uranium mines are more recent than this, there might be a greater likelihood that PRP funding could be secured.

Available documentation for mine cleanups on USFS land follows the CERCLA process for removal actions. Included are streamlined risk assessments for human health and ecological receptors (comparison with benchmarks).

Uranium mines made up only an estimated 3.3 percent of USFS's abandoned mine inventory according to a 1995 inventory report (USFS 1995).

3.3.4 Navajo Nation

The Navajo Nation has been identified as an area where uranium mines may pose significant risks—there are no land use restrictions on these lands. Residential use is possible anywhere on the Navajo Reservation, and lands could be accessed regularly even if residences are not present. Therefore, mines on these lands are potentially more accessible compared to those on public lands. Several organizations have been involved in uranium mine reclamation activities on the Navajo Nation. The Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) has addressed physical hazards and surface reclamation of the uranium mines. EPA Region 9 led the Navajo Abandoned Uranium Mines Project—an effort to catalog and screen mines on the Navajo Nation. Subsequently, this information was used in a multi-agency, 5-year planning effort to address long-term human health and environmental exposures posed not only by mines, but also by milling-related contamination. Following is a summary of these programs.

The Navajo Abandoned Mine Lands Reclamation Program. NAMLRP was approved by the Office of Surface Mining in 1988, giving the Navajo Nation the authority to use AML funds for abandoned mine reclamation. In May 1994, the Secretary of Interior concurred with NAMLRP's certification that all eligible priority-1 and priority-2 abandoned coal mines were reclaimed. Since receiving certification, AML funds were used by NAMLRP for reclamation of uranium and some copper mines. The final non-coal reclamation project was completed in May 2004. It was estimated that approximately 90 percent of the mines were reclaimed; those that were not were in remote locations and determined to be inaccessible (NAMLRP 2013). Since that time

AML funding has been used primarily for Public Facility Projects, as well as for monitoring and maintenance of past reclamation work (Maldonado 2005).

NAMLRP reclaimed their mines according to guidelines for management of three classes of materials at mine sites. Class A materials are those near background concentrations (around 2 pCi/g radium-226); Class B materials are above background but below 25 pCi/g (50 microroentgens per hour [μR/h]); Class C materials are above 25 pCi/g (50 μR/h). The general management approach for these materials is to bury Class C followed by Class B. Class A materials are placed as a final cover (NAMLRP 2013).

Navajo Abandoned Uranium Mines Project. In November 1993, U.S. congressional subcommittee hearings were conducted in which Navajo representatives presented testimony about uranium mines on the Navajo Nation. Assistance was requested to determine if the mines posed a health risk to Navajo residents. In 1994, EPA Region 9 initiated the Navajo Abandoned Uranium Mines Project (EPA 2007a). Other participating agencies included the Navajo Nation Environmental Protection Agency (Navajo Nation EPA), the U.S. Army Corps of Engineers, and NAMLRP.

A comprehensive survey of mines on the Navajo Nation was completed in 2007 and consisted of a screening assessment report and an atlas with geospatial data (EPA 2007a). The purpose of the study was to evaluate potential long-term exposure risks to human health and the environment. The survey included the mines that had been reclaimed by NAMLRP. Mine location data were used in combination with data for other geographic features, including water wells, surface drainages (perennial or intermittent), and potentially habitable structures. This information was used to "score" the mine sites based on a modified hazard ranking system scoring method that takes into account the potential for exposures through soil, air, surface water, and groundwater pathways (EPA 2007a). A key purpose of the study was to identify areas with the highest apparent levels of risk for further investigation. Over 1,200 known mine features were evaluated. Results of this study were used as a starting point for development of the Navajo Nation Five-Year Plan.

Five-Year Plan for Uranium Contamination in the Navajo Nation. In October 2007, Congress requested development of a Five-Year Plan to address uranium contamination in the Navajo Nation (BIA, DOE, EPA, IHS, and NRC 2008). This was a multiagency effort (U.S. Bureau of Indian Affairs, DOE, EPA Region 9, Indian Health Service, Navajo Nation EPA, and NRC) in consultation with the Navajo Nation. The scope of the Five-Year Plan includes uranium mines but also addresses contamination from uranium milling (UMTRCA Title I and Title II sites). The main tasks associated with uranium mines included assessing and remediating contaminated structures and assessing and requiring cleanup of abandoned uranium mines.

A January 2013 report (EPA 2013c) summarizes progress toward Five-Year Plan goals. With respect to contaminated structures, EPA and Navajo Nation EPA surveyed 878 structures. Those found to pose a health risk were demolished, and either the structures were rebuilt or the owners were compensated financially. A total of 34 structures and 18 residential yards were addressed.

A total of 521 mine claims were assessed between October 2008 and November 2011. EPA used a gamma radiation level of greater than 2 times background as an indication of an observed hazardous release that required further investigation. Mines with gamma radiation less than 2 times background indicated little or no current threat. Mines with gamma levels exceeding 2 times background were placed into two categories: those with levels exceeding 10 times background (226 mine claims) and those between 2 and 10 times background (177 mine claims). These mines were further evaluated to determine whether occupied structures were located within 200 feet and within 0.25 mile, resulting in 4 priority categories with a total of 70 mine claims. Detailed assessments were conducted at 45 high-priority mine sites.

The Northeast Church Rock mine was identified in the Five-Year Plan as the highest priority mine site. A CERCLA cleanup of this site is being undertaken by the PRP (General Electric/United Nuclear Corporation) with oversight by EPA, the Navajo Nation, and the State of New Mexico. Mine wastes from the site are being consolidated with those at the Church Rock UMTRCA Title II mill site, located off the Navajo Nation.

The Five-Year Plan summary identified a need to conduct cleanups of additional mines sites. Of concern are identifying suitable disposal sites for mine waste. Cleanup is being done under CERCLA authority. EPA is conducting a PRP search for the mine sites for purposes of cost recovery; to date, PRPs have been identified for 74 mine claims. Based on results conducted according to the Five-Year Plan, EPA concluded that it has a good understanding of the scope of potential exposure issues related to uranium mining on the Navajo Nation (EPA 2013a).

3.3.5 National Park Service

NPS was one of the first agencies to begin inventorying mines on NPS lands, sending out questionnaires to park managers in 1983 requesting basic information about known AML sites. The agency may have gotten a head start on other federal land management agencies due to the greater attractiveness and accessibility of National Parks compared to other public lands.

NPS consulted with DOE in the mid-1990s (Higgins and Burghardt 1994) specifically on the reclamation of uranium mines. At that time, their inventory noted 42 uranium mines within park boundaries—primarily in Canyonlands, Capital Reef, and Glen Canyon (all in Utah; no detail was provided on the 42 mines, and it is unclear how they compare with the mines in the LM mine database). It was noted that NPS's primary focus is on eliminating physical hazards and that spoils piles may be left intact. However, they did recognize the need to limit radiation exposures to employees and the general public. The assumption was that these areas would be adequately protective if exposures were limited to 10 mrem/yr. A 1996 paper regarding uranium mines on NPS lands acknowledged the need to manage park lands based on their most likely use—exposure to both visitors and employees should be considered and appropriate measures taken (Burghardt 1996). An inventory of uranium mine features completed in September 2011 indicated that 53 of the 115 mine features identified at uranium mines in Utah national parks had been closed between 1990 and 2003.

An interim system-wide inventory of NPS mine features was conducted from FY 2010 through FY 2012 (NPS 2013). The inventory includes not only hardrock mines, but also sites exploited for industrial minerals, aggregate, coal, and oil and gas. Of the 23,182 features included in the inventory, 5.8 percent have already received "long-term treatment," 12.4 percent are in need of treatment, and 81.8 percent do not require further action. A majority of features in the NPS inventory that require mitigation (60 percent) are located in the California desert region.

Approximately 28 percent are located in the Intermountain Region, which includes states containing uranium mines.

The NPS priority ranking methodology involves identifying features or characteristics that are common at abandoned mines and assigning each feature a high, medium, or low priority. Sites are assigned ratings based on hazards present, accessibility, resource significance (e.g., presence or absence of endangered species), and resource impacts (alteration of waters/soils). Prioritization of sites is based on a combination of hazards and resource impacts. Accessibility, while important, is not used to prioritize sites but is considered when determining priorities for implementation. It is noted that truly hazardous features should not be ranked lower due to a site's remoteness, because park visitors do utilize remote backcountry areas. It is of note that the potential for radiation is considered a high-priority hazard. Therefore, all uranium mines are assumed to have a high ranking.

Feature-level rankings for a mine site are combined to provide a site-level ranking that takes into account the numbers of features present. The majority of NPS features that still require mitigation are high-priority hazards where there is a risk of serious injury or where there is severe environmental or cultural resource damage. It appears that emphasis for NPS mine sites is on addressing physical hazards. They cite many different mitigation methods that are used.

3.3.6 States

New Mexico

The New Mexico Abandoned Mine Land (NMAML) program was approved in June 1981. Since that time most of the SMCRA funding it received has been used to reclaim high-priority coal mine features; some has been directed to high-priority non-coal features. NMAML has partnered with BLM and Navajo AML to address concerns associated with uranium mining, particularly in the Grants Mineral Belt, where at least 96 mines and 5 mill sites are estimated to remain. NMAML notes that the most serious remaining hazards within the state are associated with mineral mining (NMAML 2011).

The State of New Mexico Mining and Minerals Division has been working in collaboration with state, federal, and tribal agencies to inventory and prioritize the reclamation of uranium mines on a statewide basis (DeLay et al. 2009). The inventory identified a total of 259 uranium mines, 137 of which had no documented reclamation. The majority of the mines were on tribal lands; slightly fewer were on private and federal lands. Mines in the database were scored according to five variables: number of open/unguarded mine hazards, gamma radiation measurements 1 meter above the ground, distance to nearest well, distance to and clustering of nearest drainage, and the number of spatial clustering of dwellings within a 5-mile radius. Scores for each variable were combined. Mines were assigned to one of four priority categories based on natural breaks in the scores, with 1 being highest priority and 4 being the lowest.

In 2009, a multi-agency effort was initiated to address the health and environmental impacts of the uranium legacy in the Grants Mining District (GMD) in New Mexico. EPA Region 6 was responsible for coordinating this effort. Mines on the Navajo Nation were excluded, as they are being addressed through the Five-Year Plan for Uranium Contamination on the Navajo Nation (discussed above). The EPA Region 6 Five-Year Plan (EPA 2010a) identified 97 abandoned uranium mines in the GMD. The plan identified six objectives; one of these was "Assessment and cleanup of legacy uranium mines." EPA planned to use CERCLA authority to recover costs and compel work at these mines, as appropriate. The plan noted that for mines located on BLM land, BLM would use its CERCLA authority to address these mines. The Laguna Pueblo/Jackpile mine was singled out specifically in the Five-Year Plan. EPA is using its Superfund authority to conduct site investigations at this site. This mine was formally added to the NPL effective January 13, 2014 (78 FR 75475). Other mines currently undergoing remediation include the San Mateo mine on USFS land; the Johnny M mine, where the responsible party is conducting a site investigation pursuant to an EPA Administrative Order on Consent for Removal Action; and possibly some mines on BLM land. There are no cleanups planned for the remainder of the mines at this time.

EPA Region 6 has conducted an aerial gamma survey throughout the GMD. Elevated gamma readings were detected at many mines, with the highest readings at wet mines in the Ambrosia Lake submining district. The New Mexico Environment Department (NMED) has completed preliminary Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) screens on most of the 97 mines and additional investigation was recommended for many, including a groundwater investigation. EPA Region 6 has performed a limited field sampling program at eight of these mines. The results confirmed that releases of hazardous substances had occurred at all eight mines. However, it is likely that these mines are too small or lack human receptors to be placed on the NPL. The EPA Region 6 Removal Program has performed a field reconnaissance of these and all the other mines in the GMD. Based on the reconnaissance, an imminent and substantial endangerment determination to warrant a CERCLA removal action will likely not be made for many of these mines since no one was observed to be living on or adjacent to the mines.

The EPA Region 6 Removal Program has been conducting a survey of residential properties and structures for excess gamma radiation and radon in the GMD since 2009. Over 800 properties and structures have been surveyed, primarily in Hispanic and Laguna and Acoma Pueblo villages, the village of Bluewater, and the subdivisions near the Homestake Mining Company NPL site (known as Mormon Farms). Mine wastes used as building materials have been found at a number of residential properties and are being cleaned up as CERCLA removal actions.

BLM is reviewing a proposal for reclaiming the Rio Puerco mine that was submitted by the Uranium Company of New Mexico. The proposed reclamation includes onsite waste burial. The PRPs completed remediation work at the San Mateo mine, which included placement of wastes in a 24-acre onsite repository. PRPs will perform operation and maintenance for 5 years, and then turn the site over to USFS for future custodial responsibility.

As part of the five-year planning effort, EPA Region 6 is working with other federal, state and tribal agencies, including NMED, to investigate the extent of ground water contamination in the GMD. EPA Region 6 and NMED are coordinating this effort. Information provided by EPA noted that "ninety-seven (97) legacy uranium mines have been identified in the GMD, the majority (81) in the Ambrosia Lake sub-mining district and within the San Mateo Creek drainage basin. Forty-eight (48) of these mines were operated as wet mines, with the underground workings dewatered to allow mining of the ore. Over the years of operation billions of gallons of mine water from these 48 mines were pumped to the surface and discharged into nearby arroyos and creeks, resulting in significant re-saturation and contamination of the shallow alluvium and underlying bedrock aquifers." According to the GMD five-year plan (EPA 2010), "current-day impacts to regional groundwater quality from legacy uranium sites for the most part have not been assessed, but are indicated by the results from historical data and limited assessment and abatement work on a few mine sites within the Ambrosia Lake and Laguna subdistricts that have been ordered by the State under its ground water abatement regulations."

The Five-Year Plan effort also involved the assessment and cleanup of contaminated structures located near the mines or constructed with mine materials. By June 2012, 548 structures had been assessed; 151 structures had radioactive contamination above action levels. These structures are being addressed by various types of removal actions, including structure demolition, soil removal, and radon abatement system installation. Continued testing and cleanup for the remaining structures is planned.

Utah

The Utah Abandoned Mine Reclamation Program (AMRP) was created within the Division of Oil, Gas and Mining, a division of the Department of Natural Resources. In 1981 Utah received primacy for regulation of coal mining and reclamation under SMCRA. Utah received primacy from the Office of Surface Mining in 1983 for AMRP funded by fees paid by the coal industry into the federal AML fund. AMRP protects public health and safety from hazards at abandoned mines and restores lands damaged by past unregulated mining.

In its first decade of work, AMRP focused mainly on the reclamation of coal mines. By 1992, AMRP began reclamation of abandoned non-coal and uranium mines primarily by the mitigation of physical hazards (e.g., the closure of shafts and adits). In general, environmental degradation is addressed only at coal mines as specified by SMCRA rules.

A comprehensive inventory of abandoned mines has not been completed for the entire state of Utah. Instead, mining districts and areas selected for inventory are prioritized using a geographic information system (GIS)-based model (Rohrer, et al., 2008). The model assigns scores or weights to numbers of potential mine features (e.g., openings), proximity to population centers, and proximity to roads. The model factors in the density of mines and gives greater weight to areas with multiple mines. In this manner, the focus is on prioritizing potential projects as opposed to individual mines. One recognized shortcoming of the current model is that it uses only census data for resident populations and doesn't account for recreational use of the many public lands in the state (42% of the Utah land area is managed by the BLM). Different ways to factor in this type of land use are being explored. To date, use of the model has resulted in the selection of projects that are defensible and that do the most good.

AMRP has estimated that there are approximately 20,000 mine features with associated environmental and physical hazards eligible for reclamation under SMCRA funding in Utah. As of January 2014, approximately 6,000 of these features had been reclaimed since the inception of the program. AMRP has inventoried and reclaimed approximately 933 uranium mine adits and shafts identified as physical hazards. Approximately 400 more have been inventoried and are in various phases of engineering and construction planning. It is estimated that another 300 to 700 remain to be inventoried.

Mine waste dumps and uranium-mine-associated environmental degradation have not been systematically tracked during abandoned mine inventories in Utah. However, AMRP has performed reclamation and remediation at uranium mine projects that have been funded by non-SMCRA dollars in cooperation with other agencies. The Cottonwood Wash project was completed in 2004 in cooperation with BLM, USFS, and the Utah Department of Environmental Quality. The La Sal project was completed in 2011 in cooperation with BLM and DOE. Both of these projects involved the reclamation and remediation of waste dumps, access roads, and surface water along with the closure of abandoned adits and shafts.

Wyoming

The Wyoming Abandoned Mine Land Reclamation plan was approved in February 1983 by the U.S. Secretary of Interior. The State has used SMCRA funding for non-coal reclamation. Most of the uranium mines in Wyoming are open-pit mines.

Wyoming has a separate uranium mine inventory, and significant SMCRA funding has been used to address uranium mines. The BLM Wyoming office is partnering with the state AML program and DOE to address uranium mines (BLM 2006, Wyoming chapter; http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands/AML_Publications/national_aml_strategic.html). Wyoming has developed guidance specific to cleanup of lands with radiological contamination. Their surface material cleanup standard is 20 pCi/g of Ra-226 (inclusive of background) for all non-residential areas. The State's practice is to encapsulate all materials exceeding this standard (which equates to field readings of 84.8 µR/h). Materials are isolated in areas that are well above the expected water table and below root zone depths. The isolation areas are constructed in clean unclassified fill, capped with clean unclassified fill, protected against erosion by the grading designs, covered with topsoil/cover soil, and seeded. In addition to isolating radiological materials, the State also tries to isolate mining-related materials that have acid-generating potential (e.g., visible pyrite crystals).

According to Western Governors Association/National Mining Association data, Wyoming funding in FY 1997 for AML was $22,000,000 (Table 7) in SMCRA funds distributed through OSM, which was more than all other states/agencies combined. The 2008 GAO report looked at expenditures from 1998 through 2007. It was noted that Wyoming was the largest recipient of OSM grants, receiving $99 million (Table 8; presumably this is in addition to the $22 million in FY 1997). Grant amounts are based on the percentage of the coal fee (assessed per ton of coal produced) paid into the AML fund, and Wyoming is the largest producer of coal in the U.S.

Colorado

The Colorado Division of Reclamation, Mining and Safety (DRMS) within the Department of Natural Resources has responsibility for safeguarding abandoned mines within the state. The inactive mine reclamation program began in 1980. An estimated 23,000 abandoned mines are located in Colorado; based on the LM mine database, only 6.7 percent of these (1,539) are uranium mines. According to DRMS, safety hazards have been addressed at more than a quarter of the total abandoned mines (http://mining.state.co.us/Programs/Abandoned/Pages/impwelcomepage.aspx, accessed October 28, 2013).

The Colorado Geological Survey completed an inventory of environmental degradation associated with abandoned and inactive mines on USFS lands in Colorado during the years 1991 through 1999. In the course of the inventory, areas with natural acid rock drainage were also noted. Approximately 18,000 abandoned-mine-related features were inventoried, including about 900 features with environmental problems considered significant enough to warrant further investigation. With the information provided by the inventory, USFS, in cooperation with other agencies, has been able to prioritize abandoned mines for reclamation. Mines are rated (i.e., given a numerical assignment) based on both environmental degradation and physical hazards for prioritization. In most cases, cleanup is approached on a watershed basis. Mines in priority watersheds were selected for reclamation first. DRMS and USFS have a cooperative agreement to facilitate closure of abandoned mines (see Section 3.3.7).

3.3.7 Multi-Party Efforts

One criterion that several agencies consider in prioritizing mine lands for cleanup is the ability to form multi-party partnerships and leverage funding from several sources. Particularly for watershed-scale projects, lands may be under private and public ownership; public lands may be under multiple jurisdictions. The Cottonwood Wash watershed in Utah is a 143,000-acre area where numerous uranium mines are located. Surface water samples showed elevated gross alpha radiation, and the area was designated as a state impaired-water site under CWA. BLM lands make up 33 percent of the watershed and USFS about 60 percent. CWA was the main regulatory driver, but physical hazards were also addressed. The NEPA process was used for decision-making purposes. The main goals of the project were to close mine openings, remove/reclaim waste piles and roads, plug drill holes, and seed disturbed areas to stabilize and create habitat. Cleanup presented unique challenges due to a number of factors, including cultural resources (pre-pueblo ruins), the presence of active mining claimants and rights-of-entry, historic mining districts, wildlife, and mixed land ownership.

The State of Colorado and USFS, Rocky Mountain Region, entered into a cooperative agreement to facilitate the physical and environmental closure of abandoned mines on USFS land within the state of Colorado (State of Colorado/USFS 2009). This agreement calls for coordination between DRMS and USFS. USFS has the lead for identifying the sites in need of environmental/physical closures, and DRMS is the lead for project implementation. USFS provides support for NEPA, cultural resource surveys, and wildlife clearances as well as maps, aerial photographs, and access information. Project plans undergo joint agency review.

The Animas River Watershed in Colorado and the Boulder River Watershed in Montana, though not uranium-related, are examples of large, multi-party projects that involved collaboration between government agencies, public interest groups, and industry. The Luttrell Pit, established as part of the Boulder River cleanup effort, is the first regional joint mine waste repository to be established in the United States (BLM 2007). The project establishes a precedent for disposal of abandoned mine waste by multiple land management agencies. EPA has since issued a policy to encourage joint repositories for mixed-ownership cleanups (EPA 2005).

4.0 Prioritization Approach

Because agencies, tribes, and states have created prioritization approaches for their own use based on differing missions and regulations, it may not be possible or desirable to create a single ranking for all mines. Instead, the following discussion identifies a generic approach to prioritizing abandoned uranium mines by ranking different categories of mine features. A collective consideration of these features could be used to prioritize a set of individual mines. This approach is based on prioritization methods in use by others and on information analyzed by LM for the Report to Congress.

Common to most prioritization methods are a consideration of physical hazards, radiological/chemical hazards (i.e., contaminants), accessibility, and cleanup status. For some agencies, physical hazards have a higher priority than contamination hazards (e.g., those conducting cleanup under SMCRA), while for others human health/environmental hazards are the main priority (e.g., EPA under CERCLA or CWA). BLM establishes both physical site priorities and watershed priorities. In either case, a major consideration in establishing which specific mines to address is accessibility and proximity to populations or other attractive features. The major factors used for prioritizing mines for reclamation/remediation are discussed in this section in the context of the LM mine database.

It should be noted that specific prioritization methods may also include other factors that are not described in detail here, such as proximity to other mines, use of the area by protected species, and cost. In some cases, priorities may be dictated by the source of funding. A recent example is the Tronox (Anadarko/Kerr-McGee) settlement in April 2014, in which approximately $1B will be available for EPA to use to clean up about 50 specific (former Kerr-McGee) uranium mines on the Navajo Nation. Funding will be directed to these mines, despite the fact that others may be higher priority based on other considerations (as discussed in section 3.3.4).

4.1 Physical Hazards

The following conclusions may be made regarding physical hazards associated with mines in the LM mine database:

- Unreclaimed mines pose the greatest physical hazards; larger mines have greater numbers of hazards than smaller mines, though all size mines can have physical hazards that may pose serious risks. Cleanup status and mine stability are probably more important than size in determining the severity of physical threat posed by a given mine. There is no good surrogate parameter to judge site stability short of visiting the site.
- It is assumed that the most severe physical hazards have been addressed at mines that are partially reclaimed and that all physical hazards have been eliminated at mines that have been reclaimed. Reclamation status is not known for over 86 percent of the mines in the LM mine database.

Table 12 provides an example of a relative ranking of physical mine characteristics based on the review of prioritization schemes discussed in Section 3.2. This example is based largely on a ranking system used by the National Park Service (NPS 2013). It is generally accepted that the most severe physical risks are associated with vertical openings in which a fall could lead to death or serious injury. These are of greater hazard where their presence is not obvious or where they are associated with unstable geology or structures. These would be considered to pose "extreme dangers" in the terminology of SMCRA. Based on the work conducted for the topic report on location/status, these features are associated with all sizes of mines, though they are more numerous with larger mines that have the most extensive workings. Short of visiting each mine site, it is not possible to predict site stability. For the most part, the most hazardous features are associated with underground mines; at open-pit mines, hazardous features (e.g., highwalls) are generally more obvious. However, open pits filled with water can be tempting to swimmers. Waters are often colder than expected and can obscure ledges, equipment, and other physical hazards. According to statistics compiled by the Mine Safety and Health Administration, drowning is the leading cause of death associated with abandoned mine sites (http://www.msha.gov/SOSA/previousfatalstats.asp, accessed October 28, 2013).

Table 12. Physical Hazards

Relative Hazard Rank	Mine Characteristics[a]	Potential Injury
High	Shafts, irrespirable air, death or injury has occurred; deep pools or openings, major collapse zones; unstable structures; greater numbers of features; highwalls >10 feet, drop-offs not apparent	Serious to fatal injury possible
Medium	Portals, vents, highwalls >10 feet; drop-offs apparent; seemingly stable conditions	Moderate injury possible
Low	Rock piles, pits/trenches, features visible; fewer features; highwalls <10 feet where drop-offs are common and naturally occur	Minimal injury possible (tripping, bumping head)

[a] Low and medium ranking characteristics might also be present at mines with higher-ranking characteristics

4.2 Proximity

While many ranking systems assign scores to individual mines based on the number of physical hazards at a site, this measure may not be a good indication of the actual risk posed by one mine site compared to another. A mine with one hazardous feature located near a populated area may be a bigger threat than a remote mine with several features. Thus, for sites with physical hazards present, BLM (2011) based priorities solely on proximity to a populated or attractive area rather than on the severity or number of physical features (see Table 13). Note that "attractive areas" may include facilities such as recreation areas, trailheads, trails, campgrounds, "ghost towns" and other nonresidential areas. For public lands, proximity to these features is generally more important in prioritizing sites than is proximity to population centers. Distances used by different agencies for defining categories of proximity include one-quarter mile (BLM 2011), 1 mile, and 5 miles (NPS 2013).

As discussed in the location/status topic report, mines included in the LM mine database have a range of cleanup statuses. Mine status will likely be a more useful consideration for physical hazard prioritization than will mine size. Proximity may also be a factor in prioritization from the standpoint of radiological hazards posed by uranium mines. On the Navajo Nation, where residential use in mine areas is possible, proximity of mines to structures was used to prioritize mines for cleanup (see Table 10). Distances used were much closer than those for physical hazard sites. Radiological hazards are discussed further in Section 4.3.

Table 13. Proximity Ranking Systems

Ranking	BLM 2011 (Recreational)	NPS 2013 (Recreational)
High	Within 0.25 mile of populated place[a] or school	Good road or dirt road to/by mine site
Medium	Within 0.25 mile of historic mining town, historic schools, recreation area, park, camp, trails	Dirt road or path within 1 mile; easy hike >5 miles or moderate hike up to 5 miles
Low	>0.25 mile from populated place	Moderate hike >5 miles or hard hike <5 miles

Notes:
Mine size is not relevant for physical hazard risk; all size mines have features that can result in serious injury.
[a] Populated place is defined as a city, town, or village; distance is measured from the center of the original place (e.g., city hall, post office, town square).

Table 14 and Table 15 summarize proximity of mines to roads, schools, and populations based on land ownership. These statistics, from the risk topic report (based on mine numbers in the LM mine database), illustrate the fact that most mines are located in remote areas. The vast majority (84 percent) are located more than a mile from a roadway (local, county, state, or interstate). More than a third of all mines have no residents within a one-mile distance. Only about 3 percent of the mines are located in areas having a population of 1,000 or more persons within a 5 mile radius.

Table 14. Number of Mines within Distance Intervals from Roads and Schools

Distance (miles)	Roads		Schools	
	Federal[a]	Tribal/Private/State	Federal	Tribal/Private/State
<0.5	177	79	2	12
>0.5 – 1	174	49	5	3
>1 – 5	1195	282	153	80
>5 – 10	609	242	575	168
>10	148	59	1,568	448

[a] 83% BLM; 15% USFS

Table 15. Number of Mines within Combined Population and Distance Intervals

Population	Within 0.25 mi		Within 0.5 mi		Within 1 mi	
	Federal[a]	Tribal/Private/ State	Federal	Tribal/Private/ State	Federal	Tribal/Private/ State
0	1,368	336	1,235	239	1,055	194
>0 – 1	722	222	544	167	296	80
>1 – 10	201	113	428	225	674	233
>10 – 100	12	35	91	55	260	160
>100 – 1,000	0	5	5	22	18	37
>1,000	0	0	0	3	0	7

[a] 83% BLM; 15% USFS

4.3 Radiological Hazards

The degree of radiological hazard is mainly dependent on the exposure duration at a given mine site. The highest exposures would be for a resident living on a mine site, although EPA (2007c) notes that close to the mine. Note that conclusions drawn in this section were based on the evaluation of "average mines" in the risk topic paper. Other exposure scenarios are possible (e.g., repeated use of mine roads by all-terrain-vehicle enthusiasts). Observations here are limited to the scenarios evaluated in the risk topic paper and for comparison purposes only. Major observations from the risk evaluation include:

- While reclamation activities are not designed to specifically address radiological contamination, it is likely that reclamation activities (sealing or blocking adits, applying cover to waste rock piles for revegetation) can reduce risks significantly. Depending on the method of adit closure, potential exposures to radon could be unchanged or they could be essentially eliminated compared to the unreclaimed state. For federal public lands, a recreational use scenario most likely applies for exposure to mine-related contamination. For the Navajo Nation and mines on private land, residential land use is possible.
- Based on the acceptable CERCLA risk range of 10^{-4} to 10^{-6}, remediation of mine sites with potential for onsite residential use are clearly justifiable, particularly if mine waste has been used for building materials. Risks for all onsite residential exposure scenarios exceed the upper end of the CERCLA risk range. Offsite residential use is within the acceptable CERCLA risk range for all mines sizes and for distances as close as 100 meters (m).
- Risks associated with construction of future residences on reclaimed/remediated mine lands will be dependent primarily on surface cleanup levels that can be achieved. EPA's CERCLA preliminary remediation goal for a residential exposure scenario to meet an excess cancer risk level of 10^{-4} is 1.2 pCi/g of radium-226 above background (EPA 2007c).
- Frequent onsite visits to mine sites and repeated recreational use can result in risks exceeding the CERCLA risk range. For example, if a person spends an hour a day at even a small mine site for 10 years, the excess lifetime cancer risk would exceed 1×10^{-4} (1.8×10^{-4}) based on external radiation exposure. Repeated exposures at mine adits would also result in unacceptable risks based on inhalation of radon (4 hours of exposure at a small mine results in a risk of 1.6×10^{-4}).

Table 16 summarizes potential land use and size categories for mines in the LM mine database. The numbers of mines in each category is inversely related to the size represented. Small mines make up 46 percent of the total number. Additionally, proportionally more mines are located on lands that are likely to be used for recreational purposes as compared to onsite residential use. Mine areas with potential residential use include those on U.S. Bureau of Indian Affairs or Indian allotment/trust, private, state, and non-federal lands (includes all onsite scenarios). Potential recreational use mine lands include those managed wholly or partly by federal land management agencies. There are some mines on land managed by federal agencies where recreational activities would probably not be allowed, but the number of such mines is small (e.g., there are two mines located on U.S. Department of Defense managed land). Offsite residential radiological exposures could occur for any mines located on nonpublic lands or close to the boundary of public/non-public lands. Risks are higher for locations closest to the mine sites. However, even hypothetical residences located 100 m from large mines equate to risks within the acceptable CERCLA risk range (3×10^{-5}). Risks associated with hypothetical residences at more likely distances are much lower.

Table 16. Comparison of Land Ownership and Size of Uranium Mines

Landowner	Small	Small/Med	Med	Med/Large	Large	Unknown Size
U.S. Bureau of Indian Affairs/ private/non-federal ownership (onsite residential use possible)	359	248	202	106	29	45
Federal ownership[a] (recreational use possible)	1,037	583	535	282	49	3
Unknown Land Ownership (potentially any risk scenario)	522	92	37	5	1	0
Total Counts	1,918	923	774	393	79	48

[a] 83% BLM; 15% USFS

Table 17 summarizes radiological doses/risks that could occur under different exposure scenarios for unremediated mine sites using results from the analyses in the risk topic report. All terms are defined as they are in the risk topic report or the location/status topic report. The ranges for risks are for small through large mines, with the smaller risks generally equating to the smaller mines. If no ranges for risk are reported, then mine size does not significantly affect risk. Because the mines in the LM mine inventory are skewed to the smaller sizes, associated risks would likely be skewed to the low end of the risk ranges as well.

Table 17. Radiological Hazard Comparison

Scenario	Major Pathways	Risk Range (small to large size mines)	Applicability/Notes
Onsite Receptor A	External radiation	1×10^{-2}	Private/state/tribal lands; house built on waste pile; 30-year duration
	Inhalation (indoor radon)	8×10^{-2} to 1×10^{-1}	
Onsite Receptor B	External radiation	2×10^{-3} to 4×10^{-3}	Private/state/tribal lands; house foundation built with waste rock; 30-year duration
	Inhalation (indoor radon)	9×10^{-2}	
Offsite Resident (100 m distance)	Inhalation (radon and particulate emissions)	1×10^{-5} to 8×10^{-5}	Any residence on land adjacent to mine site; risks decrease with distance from the mine site; 30-year duration
Recreational User (camping on waste pile; 14 days)	External radiation	2×10^{-5}	Visitor to federal public lands; assumes 2-week limit
	Inhalation	6×10^{-8} to 5×10^{-7}	
Exposure at adits (1 hour)	External radiation	1×10^{-7}	Any visitor for 1 hour at adits; any land ownership
	Inhalation	4×10^{-5} to 1×10^{-6}	
Occasional Visitor (1 hour on waste pile)	External radiation	5×10^{-8} to 7×10^{-8}	Any visitor for 1 hour at waste piles; any land ownership

The tables above assume that mines are not reclaimed. However, the location/status topic report shows that mines in the LM mine database cover a range of cleanup statuses. Table 18 shows the status of mines in the LM mine database in comparison to potential land use. Table 19 shows a comparison of status to mine size. Only the status categories from the LM mine database that most closely correlate with exposure scenarios from the risk topic report are shown on these tables.

Table 18. Comparison of Land Ownership and Status of Mines

Ownership	Remediated	Reclaimed	Closed	Unreclaimed or Unknown Status
U.S. Bureau of Indian Affairs/private/ non-federal ownership (onsite residential use possible)	0	282	6	673
Federal ownership (recreational use possible)[a]	3	118	123	2,216
Unknown land ownership (potentially any risk scenario)	0	4	1	652
Total counts	3	404	130	3,541

[a] 83% BLM; 15% USFS

Table 19. Comparison of Status and Size of Mines

	Small	Small/Med	Med	Med/Large	Large	Unknown Size
Remediated	0	1	2	0	0	0
Reclaimed	86	94	119	68	18	18
Closed	28	31	42	27	3	0
Unreclaimed or unknown status	1,797	798	607	284	57	32

Based on the risk evaluation topic report, sites that have undergone reclamation of physical hazards and some surface reclamation have significantly reduced risks compared to unreclaimed sites for certain scenarios (e.g., recreational user). Some agencies use the term “reclamation” to apply only to the mitigation of physical site hazards, but in this Report to Congress “reclamation” is assumed to include both closure of adits and the placement of cover over waste piles for the purpose of promoting revegetation. Depending on the method of adit closure, potential exposures to radon could be unchanged or they could be essentially eliminated compared to the unreclaimed state. (Note that “closed” in Table 19 and Table 20 means any method of blocking openings that prevents human access.) If bars or metal grids are used so that bats can have access, no radon reductions are likely. If adits are essentially sealed using materials such as high-density polyurethane, radon exposures could be eliminated. Blockage with rocks, cement, or other materials may create less of a seal, but significant reductions in radon exposure would still be expected. A study was conducted by the National Institute for Occupational Safety and Health to evaluate worker exposures to radon during closure of inactive uranium mines (NIOSH 2012). Based on field measurements of radon at mine openings, they found that even the use of temporary barriers at mine openings (e.g., tarps with a poor seal) caused a noticeable and immediate reduction in radon. They recommend the use of such barriers during closure of mines where radon exhalation is of concern. Based on radon measurements collected for the uranium mine project by DOE from adits at unreclaimed and reclaimed mines, it was noted in the risk topic report that closure (sealing) of mine openings reduced risks by one to two orders of magnitude.

Table 20 summarizes likely hazards, based on the risk topic report, that would be associated with mines of different cleanup status. Again, the ranges reflect the sizes of mines from small to large.

Be aware that the estimation of risks was for "average" mines (created for use in these topic reports and discussed in the cost topic report) for comparison only and is not meant to indicate conditions present at any specific mine. Additionally, the risks are based on the radon levels and radiological concentrations assumed for these average mines. See the risk evaluation topic report for further details. Likewise, the "cleanup types" listed are presented for comparison only and are not meant to indicate a correlation with the status of specific mines in the LM mine database, as discussed in the location topic report.

Table 20. Status/Risk/Land Use Summary

Cleanup Types	Physical Risks	Radiological Risks—Federal Public Lands (Recreational Scenario)		Radiological Risks—Tribal/Private Lands (Onsite Resident; 30 years)		Offsite Resident (100 m; 30 years)
		Camping (2 weeks)	Adits (1 hour)	Receptor A[a]	Receptor B[a]	
Unreclaimed	High to Medium, depending on site stability	2×10^{-5}	4×10^{-5} to 1×10^{-6}	9×10^{-2} to 1×10^{-1}	9×10^{-2}	$<1 \times 10^{-5}$ to $<8 \times 10^{-5}$
Closed (mine openings have been blocked)	Low	2×10^{-5}	Reduced; degree depends on closure method	9×10^{-2} to 1×10^{-1}	9×10^{-2}	$<1 \times 10^{-5}$ to $<8 \times 10^{-5}$
Reclaimed (6 inches cover on waste rock piles)	Low (assumes site would also be "closed")	4×10^{-6}	N/A	8×10^{-2} to 1×10^{-1}	9×10^{-2}	6×10^{-6} to 6×10^{-5}
Remediated	It is assumed that all physical risks could be removed. Remediation can reduce radiological risks to background levels. For onsite residential scenarios, significant risk reductions cannot be achieved without removing waste rock from beneath the structure in foundation materials.					

[a] These exposure scenarios are defined in the risk topic report

4.4 Environmental Considerations

The main conclusions for prioritizing uranium mines based on environmental concerns are as follows:

- Acid drainage, which is a major concern at many hardrock mines, does not appear to be as important at uranium mines. This may be based on a combination of the mineralogy of the ores and the aridity of climate in which they are located. However, surface water and groundwater contamination can be an issue where wet mining took place (e.g., Grants Mining District). In addition, under certain conditions, waste materials from pyrite-bearing formations can be acid-generating and might inhibit revegetation of mined areas (EPA 2007d). Environmental effects are most likely in areas with the highest densities of mines or the highest-producing mines. Relatively few geographic areas account for the majority of mines and production, and so mines in these areas could be prioritized based on potential environmental concerns. A number of these watersheds have already been identified as priorities by various agencies.
- Pit lakes can pose not only physical but also environmental hazards.

As discussed previously, a number of agencies prioritize AML based on their potential to result in environmental damage due to impacts of mines on surface water or groundwater. Impacts can be due to releases of chemical constituents that result in the violation of a water quality standard. Mines can also impact characteristics such as sediment loads, salinity, and other parameters that affect the ability of a watershed to support a healthy ecosystem.

Under Section 303 of the CWA, states, territories, and authorized tribes, collectively referred to in the Act as "states," are required to establish water quality standards, monitor and assess surface water bodies, and develop a "303(d) list." Listing a water body on a 303(d) list requires states to review their water quality standards, evaluate available monitoring data, and determine if adequate controls are in place for point and nonpoint sources of pollutants. States use this information to identify those waters not meeting the applicable water quality standards (referred to as "impaired waters") or having declining trends (referred to as "threatened waters"), after pollution controls are in place. States are required to submit their 303(d) lists by April 1 of even-numbered years. EPA's Assessment and TMDL Tracking and Implementation System (ATTAINS) provides state-reported data on the condition of monitored surface waters (EPA 2009b).

Figure 2 and Figure 3 show watersheds for the western United States by the number of uranium mines they contain and the tonnage they produced, respectively. Table 21 and Table 22 include the watersheds (based on cataloguing units) that have the greatest numbers of mines and greatest tonnage of ore production, respectively, based on the LM mine database. The tables also note whether any listed, impaired, or threatened waters from the 303(d) lists are included in each watershed. No cause and effect relationship is implied between the presence of uranium mines and impaired waters. This information was obtained from EPA water quality assessment reports available through the USGS **Science in Your Watershed** website (http://water.usgs.gov/wsc/index.html, accessed October 1, 2013). Several of the listed watersheds are priority watersheds for BLM state offices under the AML program and are also noted in the tables. While the greatest number of uranium mines are located in Colorado, none of the watersheds with significant numbers of these mines were listed as a priority by Colorado BLM. Many of the priority watersheds for the Colorado BLM were located in other hardrock mining areas (e.g., precious metals).

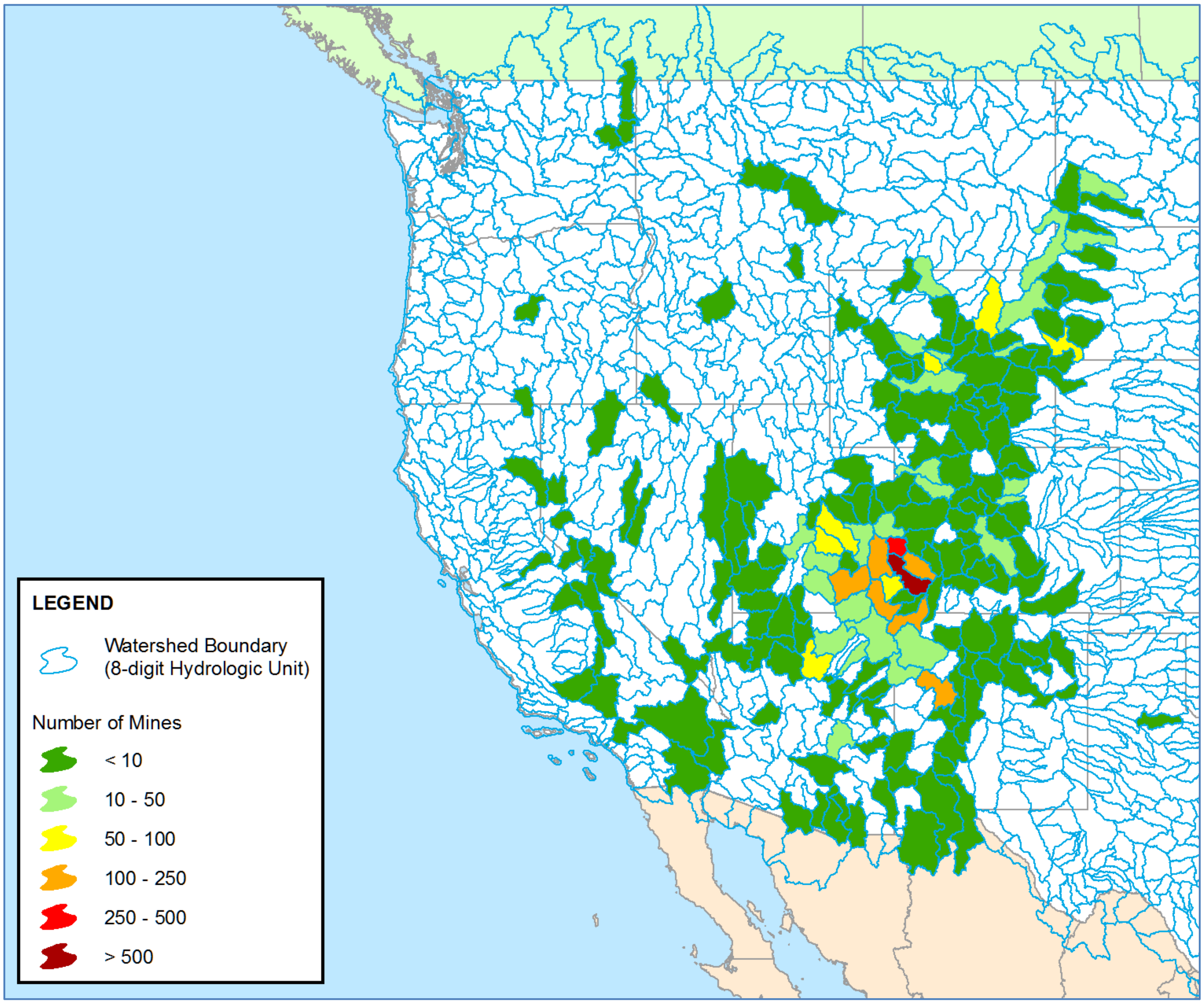


Figure 2. Watersheds for the Western United States by Number of Mines

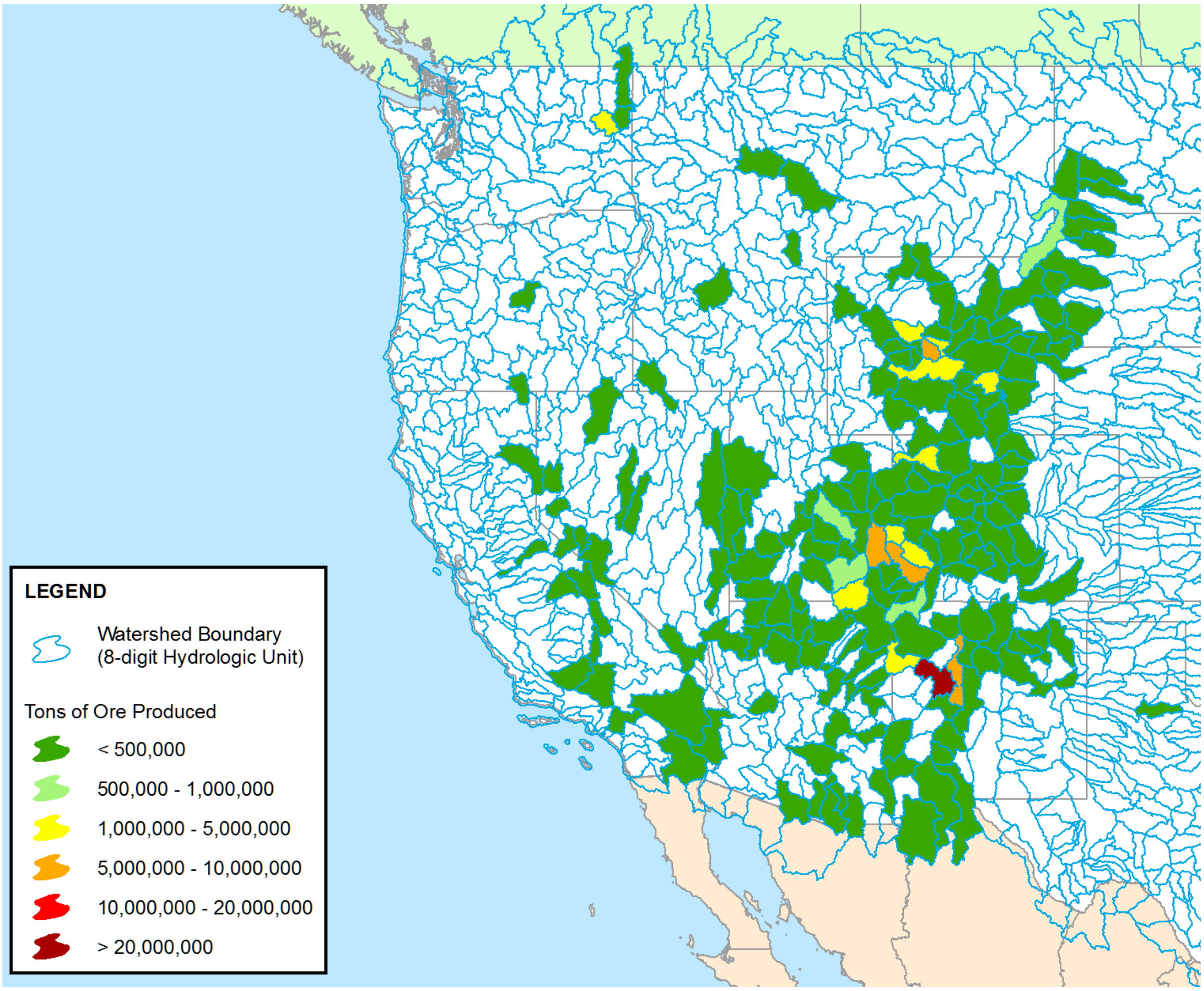


Figure 3. Watersheds for the Western United States by Tons of Ore Produced

Table 21. Watersheds with Greatest Numbers of Uranium Mines

Watershed Name (HUC8)	Number of Mines	State(s)	Notes
Upper Dolores (14030002)	697	Utah, Colorado	Includes La Sal Creek—Utah BLM priority watershed; 3 listed waters
Lower Dolores (14030004)	360	Utah, Colorado	1 impaired water
San Miguel (14030003)	232	Colorado	No listed waters
Upper Colorado-Kane Springs (14030005)	220	Utah	Includes Browns Hole USGS study site; 6 listed waters
Upper Lake Powell (14070001)	171	Utah	Includes 3 Utah BLM priorities—Red, Fry, White Canyons; no listed waters
Lower San Juan–Four Corners (14080201)	121	Four Corners	Includes Cottonwood Wash; 2 impaired waters
Middle San Juan (14080105)	112	New Mexico, Colorado, Arizona	1 listed and 3 impaired waters
Rio San Jose (13020207)	111	New Mexico	1 listed water
San Rafael (14060009)	99	Utah	3 listed waters
Agnostura Reservoir (10120106)	94	South Dakota	7 listed waters
Lower Little Colorado (15020016)	87	Arizona	No listed waters
Muddy (14070002)	74	Utah	2 listed waters
Montezuma (14080203)	64	Utah, Colorado	1 impaired water
Upper Powder (10090202)	54	Wyoming	6 listed waters
Muskrat (10080004)	51	Wyoming	0 listed waters
Westwater Canyon (14030001)	50	Utah, Colorado	3 listed waters
Lower San Juan (14080205)	49	Utah, Arizona	0 listed waters
Chinle (14080204)	47	Arizona	0 listed waters

Notes:
Watersheds listed in this table include 64% of the total mines in the LM mine database.
This table notes all impaired or listed water regardless of criteria; see the risk topic report for screening based on specific contaminants.

Table 22. Watersheds with Most Ore Produced

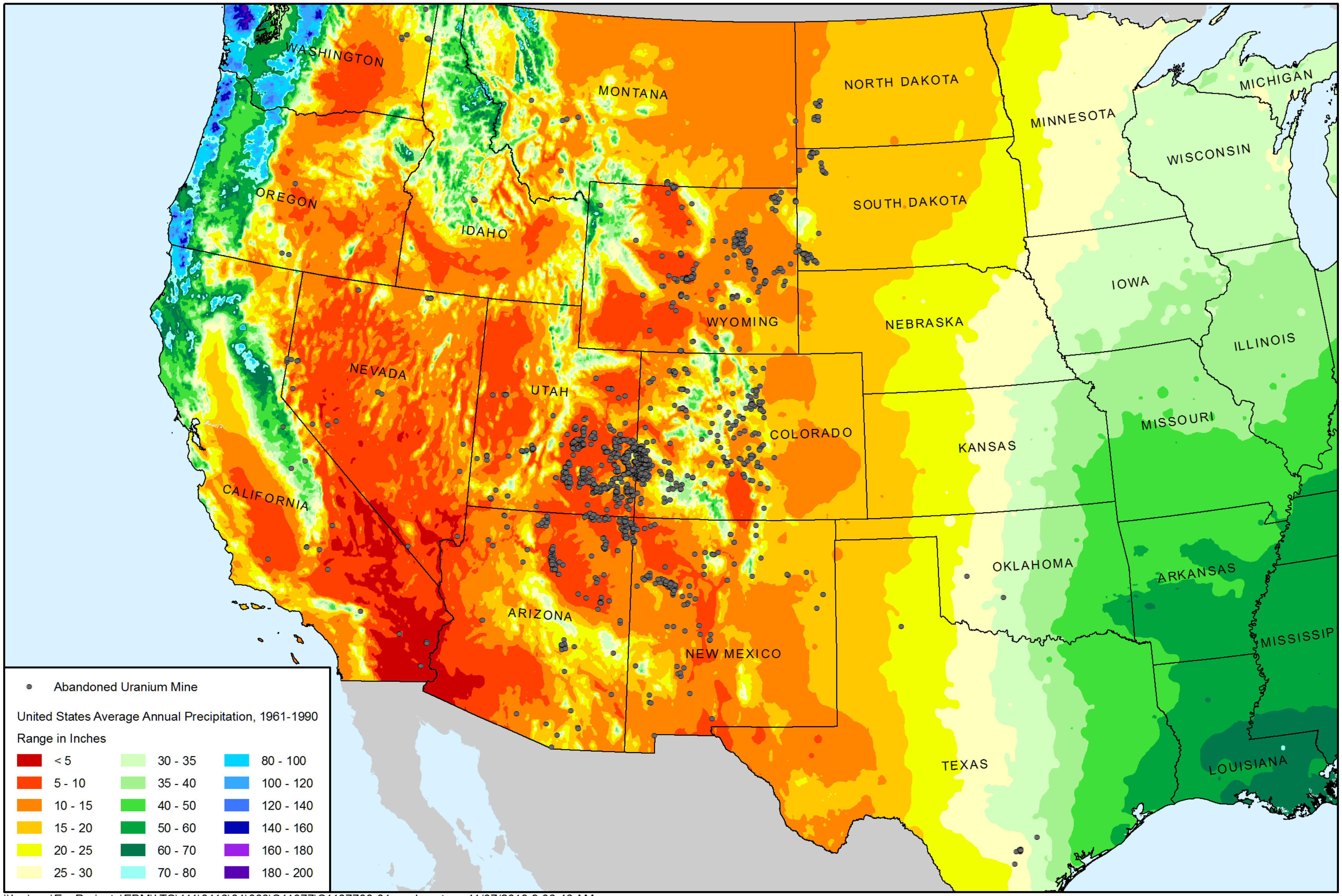
Name	Tons of Ore Produced	State(s)	Number of large mines	Number of very large mines	Notes
Rio San Jose (13020207)	22735224.66	New Mexico	14	15	1 listed water
Rio Puerco (13020204)	7808388.28	New Mexico		2	3 listed waters
Upper Colorado-Kane Springs (14030005)	7355380.82	Utah	11	5	Includes Browns Hole USGS study site; 6 listed waters
Muskrat (10080004)	6197251.43	Wyoming	8	5	0 listed waters
Upper Dolores (14030002)	5201103.65	Utah, Colorado	10	1	Includes La Sal Creek—Utah BLM priority watershed; 3 listed waters
Lower Dolores (14030004)	2507241.16	Utah, Colorado	-	6	1 impaired water
Upper Puerco (15020006)	2052478.1	New Mexico	2	1	0 listed waters
San Miguel (14030003)	1728905.62	Colorado	2	-	0 listed waters
Lower San Juan (14080205)	1419003.8	Utah, Arizona	1	1	0 impaired waters
Lower Yampa (14050002)	1321326.41	Colorado	1	2	2 listed waters
Lower Wind (10080005)	1265579.92	Wyoming	2	1	Wyoming BLM priority watershed; 2 listed waters
Sweetwater (10180006)	1187550.18	Wyoming	3	-	Wyoming BLM priority watershed; 2 listed waters
Little Medicine Bow (10180005)	1152201.29	Wyoming	2	1	No listed waters
Lower Spokane (17010307)	1147581.28	Washington	-	1	13 listed waters
Upper Lake Powell (14070001)	823635.25	Utah	1	-	Includes 3 Utah BLM priorities—Red, Fry, White Canyons; no listed waters
Middle San Juan (14080105)	716381.08	New Mexico, Colorado, Arizona	1	-	1 listed and 3 impaired waters
Upper Little Missouri (10110201)	657769.69	Montana, North Dakota, South Dakota, Wyoming	-	1	7 listed and 1 threatened waters
San Rafael (14060009)	517141.49	Utah	-	1	3 listed waters

Notes:
Watersheds listed in this table account for 91% of the uranium production from the LM mine inventory.
This table notes all impaired or listed water regardless of criteria; see risk topic report for screening based on specific contaminants.

The evaluation of potential water degradation in the risk topic report indicated the presence of few uranium mines within 2 miles of waters that were impaired on the basis of mine-related metals. EPA (2007c) noted that most of the uranium deposits with which the mines are associated do not contain appreciable amounts of sulfides, which are responsible for generating acid mine drainage. As a result, most runoff from uranium mines tends to be neutral to alkaline. However, in certain instances, these conditions could result in complexation of uranium (VI) by inorganic ions such as carbonate and enhance the solubility and mobility of this species of uranium (EPA 2010d).

Leaching of chemical constituents would be inhibited by the low amount of rainfall received in the areas where most of the uranium mines are located. Figure 4 shows locations of mines compared to average annual precipitation rates for data collected since 1961. The majority of mines are located in areas receiving less than 15 inches of precipitation a year. Additionally, rainfall events in these areas tend to be short and intense; as a consequence, many streams are only intermittent in nature. These conditions favor the transport of sediment in episodic events. A number of streams that were judged to be impaired under the CWA received that label because of problems associated with sedimentation and siltation as opposed to specific contaminants.

As discussed in Section 3.3.6, nearly half of the mines identified in the GMD were wet mines that discharged significant quantities of mine water during mining operations. Table 22 shows that 15 of the very large and 14 of the large size mines included in the LM mine database are located in the Rio San Jose watershed in the GMD, which is the watershed from which the highest volume of ore was produced. This watershed includes the San Mateo mine and the San Mateo Creek drainage basin. Impacts from these historical discharges on the groundwater in the GMD are the subject of ongoing investigations (e.g., NMED 2010). From a general prioritization perspective, the occurrence of large numbers of mines in relatively few watersheds suggests that a prioritization approach that focuses on project areas (such as developed by the State of Utah) as opposed to individual mines may be most appropriate to address environmental concerns.



\\Lm\ess\EnvProjects\EBM\LTS\111\0116\01\000\S11077\S1107700-01.mxd coatesc 11/07/2013 9:06:46 AM

Figure 4. Average Annual Precipitation of the Western United States

As noted previously, open pit mines often result in the creation of artificial pit lakes. These can pose not only a significant physical hazard, but may be of concern from an environmental standpoint as well. Water in the pit lakes can interact with minerals in the ore-bearing zones and produce elevated concentrations of mine-related constituents in the lake waters. Because of the accessibility of these areas to wildlife, particularly in a generally arid environment, these types of mines might need to be elevated in priority.

The presence of mines can result in environmental effects other than the leaching of metals into groundwater and surface water bodies. The presence of pyrite in mine wastes can generate acidity in soils and inhibit revegetation of mined areas (EPA 2007d). Though pyrite does not occur in most uranium deposits, it is characteristic of deposits in the Wyoming Basin and Texas (EPA 1995). As noted in section 3.3.6, the State of Wyoming treats acid-generating mines wastes in the same manner as radioactive mines wastes by encapsulating those materials above the water table and below plant root zones.

As discussed in the risk topic report, it is possible for radiological constituents in mine wastes to pose risks to ecological as well as human receptors. For areas with only isolated and small mines, these risks would not be expected to be significant, considering the home ranges of many wildlife species. However, areas with the greatest mine densities (or those which produced the most ore) may have resulted in more widespread land disturbance and might be a higher priority for environmental considerations, in general. While hydrologic boundaries do not necessarily correspond to boundaries of ecological habitats, Figure 2 and Figure 3 suggest that significant environmental impacts associated with uranium mines would most likely be in relatively few areas.

This page intentionally left blank

5.0 References

ANSI/HPS (American National Standards Institute/Health Physics Society), 2009. *Control and Release of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM),* ANSI/HPS N13.53.

BIA (U.S. Bureau of Indian Affairs), DOE (U.S. Department of Energy), EPA (U.S. Environmental Protection Agency), IHS (Indian Health Service), and NRC (U.S. Nuclear Regulatory Commission), 2008. *Health and Environmental Impacts of Uranium Contamination in the Navajo Nation, Five-Year Plan,* as requested by House Committee on Oversight and Government Reform, June 9.

BLM (U.S. Bureau of Land Management), 1992. *Solid Minerals Reclamation Handbook*, BLM Manual Handbook H-3042-1, April 8.

BLM (U.S. Bureau of Land Management), 1995. *United States Department of Interior Colorado Bureau of Land Management Closure/Reclamation Guidelines Abandoned Uranium Mine Sites*; supplement to Handbook H-3042-1, transmitted from Frank Salwerowicz to Ray Plieness in a letter dated November 21, 1995.

BLM (U.S. Bureau of Land Management), 2001. *Draft Solid Minerals Reclamation Handbook*, February 9.

BLM (U.S. Bureau of Land Management), 2004. *Risk Management Criteria for Metals at BLM Mining Sites*, Technical Note 390, October.

BLM (U.S. Bureau of Land Management), 2006. *The Cooperative Conservation Based Strategic Plan for the Abandoned Mine Lands Program*, March; (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands/AML_Publications/national_aml_strategic.html. accessed November 4, 2013).

BLM (U.S. Bureau of Land Management), 2007. *Abandoned Mine Land Program Policy Handbook*, BLM Handbook H-3720-1, March 20.

BLM (U.S. Bureau of Land Management), 2011. *Feasibility Study for AML Inventory, Validation and Physical Safety Closures*, September.

BLM (Bureau of Land Management), 2013a. Abandoned Mine Land Program Policy Manual BLM Manual MS-3720, September 30.

BLM (Bureau of Land Management), 2013b. Abandoned Mine Lands: A New Legacy, BLM/WO/GI-13/007-3720.

BLM (Bureau of Land Management), 2013c. Feasibility Study for AML Inventory, Validation and Physical Safety Closures, September.

BLM/USFS (U.S. Bureau of Land Management/U.S. Forest Service), 2007. *Abandoned Mine Lands: A Decade of Progress Reclaiming Hardrock Mines*, BLM Publication Number BLM-WO-GI-07-013-3720; Forest Service Publication Number FS-891, September.

Brancard, B., 2009. "New Mexico Abandoned and Inactive Uranium Mine Site Assessment and Reclamation Progress," presentation from Navajo Uranium Stakeholders Workshop, Gallup, New Mexico, November 4.

Burghardt, J.E., 1996. *Effective Management of Radiological Hazards at Abandoned Radioactive Mine and Mill Sites*, Geologic Resources Division, National Park Service, March.

California Department of Conservation, 2000. *California's Abandoned Mines: A Report on the Magnitude and Scope of the Issue in the State*, June.

Canadian Nuclear Safety Commission, 2004. *Status Report on Site Conditions and Progress of the Licensing Process for Unlicensed Uranium Tailings Management Sites with CNSC Staff's Recommendations*, CMD 04-M47, Commission Meeting, November 17.

CRCPD (Conference of Radiation Control Program Directors Inc.), 2004. *Suggested State Regulations for Control of Radiation,* April, http://www.crcpd.org/SSRCRs/default.aspx (accessed February 5, 2014).

DeLay, L.S., S.A. Lucas Kamat, and J.R. Smith, 2009." Prioritizing abandoned uranium mine land reclamation using a GIS model," poster presentation at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, Montana, May 30–June 5, 2009.

EPA (U.S. Environmental Protection Agency), 1983. *Potential Health and Environmental Hazards of Uranium Mine Wastes*, Report to Congress, EPA 520/1-83-007, June.

EPA (U.S. Environmental Protection Agency), 1985. *Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale*; Report to Congress, EPA/530-SW-85-033, December 31.

EPA (U.S. Environmental Protection Agency), 1988. *CERCLA Compliance with Other Laws Manual*, EPA/540/G-89/006, OSWER 9234.1-01, August.

EPA (U.S. Environmental Protection Agency), 1989. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, December.

EPA (U.S. Environmental Protection Agency), 1991. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, OSWER No. 9355.0-30, Don R. Clay, April 22.

EPA (U.S. Environmental Protection Agency), 1994. *Estimating Radiogenic Cancer Risks,* EPA/402-R-93-076, June.

EPA (U.S. Environmental Protection Agency), 1995. *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals, Volume 5, Uranium, EPA 530-R-94-032, January.*

EPA (U.S. Environmental Protection Agency), 1997a. *EPA's National Hardrock Mining Framework*, EPA 833-B-97-003, September.

EPA (U.S. Environmental Protection Agency), 1997b. *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, OSWER No. 9200.4-18, Steve Luftig and Larry Weinstock, August 22.

EPA (U.S. Environmental Protection Agency), 1998. *Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites*, Directive no. 9200.4-25, February 12.

EPA (U.S. Environmental Protection Agency), 2000. *Evaluation of EPA's Guidelines for Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)*, Report to Congress, EPA 402-R-00-01, June.

EPA (U.S. Environmental Protection Agency), 2001. *EPA Superfund Record of Decision, Fremont National Forest/White King and Lucky Lass Uranium Mines*, EPA/ROD/R10-01/536, September 28.

EPA (U.S. Environmental Protection Agency), 2004. *Nationwide Identification of Hardrock Mining Sites,* Evaluation Report, Report No. 2004-P-00005, Office of Inspector General, Washington, DC, March 31.

EPA (U.S. Environmental Protection Agency), 2005. *Policy on Joint Repositories at Mixed-Ownership Hardrock Mine Sites,* OSWER Directive 9200.4-38, April 26.

EPA (U.S. Environmental Protection Agency), 2006a. *Midnite Mine Superfund Site, Spokane Indian Reservation, Washington, Record of Decision*, Region 10, Office of Environmental Cleanup, September.

EPA (U.S. Environmental Protection Agency), 2006b. *Technical Report on Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining, Volume 1: Mining and Reclamation Background*, EPA-402-R-05-007, January.

EPA (U.S. Environmental Protection Agency), 2006c. *Uranium Location Database Compilation*, EPA 402-R-05-009, August.

EPA (U.S. Environmental Protection Agency), 2007a. *Abandoned Uranium Mines and the Navajo Nation, Navajo Nation AUM Screening Assessment Report and Atlas with Geospatial Data,* prepared for EPA Region 9 by U.S. Army Corps of Engineers, August.

EPA (U.S. Environmental Protection Agency), 2007b. *Interim Guiding Principles for Good Samaritan Projects at Orphan Mine Sites and Transmittal of CERCLA Administration Tool for Good Samaritans*, Memorandum, June 6.

EPA (U.S. Environmental Protection Agency), 2007c. *Technical Report on Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining, Volume 2: Investigation of Potential Health, Geographic, and Environmental Issues of Abandoned Uranium Mines*, EPA-402-R-05-007, August.

EPA (U.S. Environmental Protection Agency), 2007d. *Site contamination—acid sulfate soil materials,* EPA Guidelines, EPA 638/07, November.

EPA (U.S. Environmental Protection Agency), 2009a. *Engineering Evaluation/Cost Analysis, Northeast Church Rock Mine Site, Gallup, New Mexico*, May 30.

EPA (U.S. Environmental Protection Agency), 2009b. *Fact Sheet: Status of 2008 303(d) Impaired Waters List Submissions to EPA*, July 17.

EPA (U.S. Environmental Protection Agency), 2010a. *Assessment of Health and Environmental Impacts of Uranium Mining and Milling, Five-year Plan, Grants Mining District, New Mexico,* EPA Region 6, August.

EPA (U.S. Environmental Protection Agency), 2010b. *Request for a Time-Critical Removal Action at the Quivera Mine, McKinley County, New Mexico, Navajo Nation Indian Reservation,* Action Memorandum, August 24.

EPA (U.S. Environmental Protection Agency), 2010c. *Skyline AUM Waste Pile Site Removal Assessment Report, Navajo Nation, San Juan County, Utah*, prepared by Ecology and Environment Inc., May 25.

EPA (U.S. Environmental Protection Agency), 2010d. *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume 3, Assessment for Radionuclides Including Tritium, Radon, Strontium, Technetium, Uranium, Iodine, Radium, Thorium, Cesium, and Plutonium-Americium*, EPA/600/R-10/093, September.

EPA (U.S. Environmental Protection Agency), 2012a. *Clean Water Act § 402 National Pollutant Discharge Elimination System (NPDES) Permit Requirements for "Good Samaritans" at Orphan Mine Sites*, Memorandum, December 12.

EPA (U.S. Environmental Protection Agency), 2012b. *Removal Assessment Report, Tronox AUM Sections 32 and 33, Eastern Agency, Prewitt, McKinley County, New Mexico*, prepared by Ecology and Environment Inc., September.

EPA (U.S. Environmental Protection Agency), 2013a. *Assessment of Health and Environmental Impacts of Uranium Mining and Milling, Five-year Plan, Grants Mining District, New Mexico,* June.

EPA (U.S. Environmental Protection Agency), 2013b. *Cove Transfer Station Sites 1 and 2, Abandoned Uranium Mine Waste Removal Action Report, Navajo Nation, Cove Chapter, Apache County, Arizona*, prepared by Ecology and Environment Inc., February.

EPA (U.S. Environmental Protection Agency), 2013c. *Federal Actions to Address Impacts of Uranium Contamination in the Navajo Nation, Five-Year Plan Summary Report,* January, http://www.epa.gov/region9/superfund/navajo-nation/5-yr-plan-2008.html, accessed November 4, 2013.

Federal Mining Dialogue, 2012. *Agency Priority Setting Processes for Abandoned Mine Lands*, Summary Paper, November 6.

GAO (General Accounting Office), 1996. *Information on Efforts to Inventory Abandoned Hard Rock Mines*, GAO/RCED-96-30, February.

GAO (Government Accountability Office), 2008. *Hardrock Mining: Information on Abandoned Mines and Value and Coverage of Financial Assurances on BLM Land,* GAO-08-574T, March.

GAO (Government Accountability Office), 2009. *Hardrock Mining; Information on Types of State Royalties, Number of Abandoned Mines, and Financial Assurances on BLM Land*, GAO-09-429T, February.

GAO (Government Accountability Office), 2012. *Uranium Mining: Opportunities Exist to Improve Oversight of Financial Assurances*, GAO-12-544, May.

Higgins, R.D., and J.E. Burghardt, 1994. "Evaluation of the U.S. Department of Energy Uranium Mine Reclamation Program and How it Relates to National Park Service Reclamation Policies," memorandum to Chief, Geologic Resources Division.

Holtrop, J., 2011. "Abandoned Mined Lands: Innovative Solutions for Restoring the Environment, Improving Safety and Creating Jobs," Statement before the Committee on Natural Resources, Subcommittee on Energy and Mineral Resources, U.S. House of Representatives by Deputy Chief, National Forest System, Forest Service, U.S. Department of Agriculture, July 14.

ICRP (International Commission on Radiological Protection) 1991. *1990 Recommendations of the International Commission on Radiological Protections,* ICRP Publication 60, Annals of the ICRP 21(1-3), Oxford Pergamon Press.

Maldonado, V., 2005. *Office of Surface Mining Reclamation and Enforcement Annual Evaluation Report, Navajo Nation Abandoned Mined Lands Reclamation Program, Evaluation Year 2005*, Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior.

Miller, D.C., 2011. "Emerging Issues Under the RCRA Bevill Exclusion: The Bevill Is in the Details," Proceedings of the 57th Annual Rocky Mountain Mineral Law Institute.

NIOSH (National Institute for Occupational Safety and Health), 2012. *Health Hazard Evaluation Report: Evaluation of Exposure to Radon Progeny During Closure of Inactive Uranium Mines—Colorado*. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH HETA No. 2011-0090-3161, July.

NMAML (New Mexico Abandoned Mine Land), 2011. *Annual Evaluation Report for the New Mexico Abandoned Mine Land Reclamation Program, Evaluation Year 2011*.

NAMLRP (Navajo Abandoned Mine Lands Reclamation Program), 2013. Navajo AML/UMTRA Department, USDOE/NAMLRP Meeting presentation, May 30.

NAS (National Academy of Sciences), 1999. *Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials*, National Academies Press, January.

NCRP (National Council on Radiation Protection and Measurements), 1993. *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116, Bethesda, Maryland, March.

NMED (New Mexico Environment Department), 2010. *Geochemical Analysis and Interpretation of Ground Water Data Collected as part of the Anaconda Company Bluewater Uranium Mill Site Investigation (CERCLIS ID NMD007106891) and San Mateo Creek Site Legacy Uranium Sites Investigation (CERCLIS ID NMN00060684)*, Final Public Draft, May.

NPS (National Park Service), 2013. *Interim Inventory and Assessment of Abandoned Mineral Lands in the National Park System,* Natural Resource Technical Report, NPS/NRSS/GRD/NRTR-2013/659, January.

NRC (U.S. Nuclear Regulatory Commission), 1993. *Final Standard Review Plan for the Review of Remedial Action of Inactive Mill Tailings Sites under Title I of the Uranium Mill Tailings Radiation Control Act*, Revision 1, June.

Rohrer, J.C., J. Miles, D. Smith, and S. Fluke, 2008. *GIS as a Prioritization and Planning Tool in Abandoned Mine Reclamation*, paper presented at "Incorporating Geospatial Technologies into SMCRA Business Processes," March 25–27, 2008, Atlanta, Georgia.

State of Colorado/USFS (U.S. Forest Service), 2009. Cooperative Agreement 09-CA-11020000-074 between (1) the State of Colorado Department of Natural Resources Division of Reclamation, Mining and Safety and (2) the U.S. Forest Service, U.S. Department of Agriculture, Rocky Mountain Region, July 30.

UNC (United Nuclear Corporation), 1989. *Tailings Sand Backfill Cleanup Verification Report, Northeast Church Rock Mine*, License SUA-1475, Condition No. 33, UNC-ALO-89-230M.

USFS (U.S. Forest Service), 1995. *Distribution of Abandoned and Inactive Mines on National Forest System Lands*, General Technical Report RM-GTR-260, April.

USFS (U.S. Forest Service), 2004. *U.S. Forest Service's Abandoned Mine Land Program,* August, http://www.mining-law-reform.info/AbandonedMines.pdf (accessed September 4, 2013).

USFS (U.S. Forest Service), 2005. *Engineering Evaluation and Cost Analysis, Juniper Uranium Mine, Tuolumne County, California*, prepared by Tetra Tech EM Inc., July.

USFS (U.S. Forest Service), 2006a. *Engineering Evaluation/Cost Analysis for the King Edward Mine, Manti-LaSal National Forest,* prepared by MSE Millennium Science and Engineering Inc., January.

USFS (U.S. Forest Service), 2006b. *Riley Pass Abandoned Uranium Mines, Harding County, South Dakota, Final Engineering Evaluation/Cost Analysis (EE/CA)*, November.

USFS (U.S. Forest Service), 2008. *Final Engineering Evaluation/Cost Analysis, Workman Creek Uranium Mine Sites, Pleasant Valley Ranger District, Tonto National Forest, Arizona*, prepared by Weston Solutions Inc., October 13.

USFS (U.S. Forest Service), 2009. *Final Engineering Evaluation/Cost Analysis Report, San Mateo Uranium Mine, Cibola National Forest, New Mexico*, prepared by Science Applications International Corporation, August.

USFS (U.S. Forest Service), 2011. *Draft Engineering Evaluation/Cost Analysis, Butterfly and Burrell Mines, Rio Blanco County, Colorado*, prepared by CH2MHill, February.

USGS (United State Geological Survey), 2010a. *Assessment of Nonpoint Source Chemical Loading Potential to Watersheds Containing Uranium Waste Dumps and Human Health Hazards Associated with Uranium Exploration and Mining, Red, White, and Fry Canyons, Southeastern Utah, 2007*, Scientific Investigation Report 2010-5108.

USGS (United State Geological Survey), 2010b. *Geology, Geochemistry, and Geophysics of the Fry Canyon Uranium/Copper Project Site, Southeastern Utah—Indications of Contaminant Migration*, Scientific Investigations Report 2010-5075.

USGS (United State Geological Survey), 2012. *Assessment of Nonpoint Source Chemical Loading Potential to Watersheds Containing Uranium Waste Dumps Associated with Uranium Exploration and Mining, Browns Hole, Utah*, Scientific Investigations Report 2011-5230.

UDEQ (Utah Department of Environmental Quality) 2002. Cottonwood Wash TMDL, March.

WGA (Western Governors' Association) and NMA (National Mining Association) 1998. *Cleaning up Abandoned Mines: A Western Partnership*.

This page intentionally left blank

Appendix A

Definitions

This page intentionally left blank

5/15 standard: An informal name for a soil standard for land cleanup at UMTRCA sites. The standard is codified in 40 CFR 192 and states that the concentration of radium-226 in land shall not exceed the background level by more than (1) 5 pCi/g averaged over the first 15 cm of soil below the surface, and (2) 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface.

Agreement states: States that have entered into agreements with NRC that give them the authority to license and inspect byproduct, source, or special nuclear materials used or possessed within their borders.

ARAR (applicable or relevant and appropriate requirement): Environmental laws or requirements that are "applicable" if the specific terms of the law or regulation directly address the circumstances at a site. If not applicable, a requirement may nevertheless be "relevant and appropriate" if circumstances at the site are, based on best professional judgment, sufficiently similar to the problems or situations regulated by the requirement (EPA 1988).

Byproduct material: The tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by such solution extraction operations do not constitute "byproduct material" within this definition. Byproduct material is used only with respect to materials subject to management under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, as amended.

Extraction, beneficiation, and **processing** wastes: **Extraction** operations are those operations that initially remove ore from the earth (e.g., mining). Waste rock, overburden, and protore are common extraction wastes. **Beneficiation** is defined to include crushing; grinding; washing; dissolution; crystallization; filtration; sorting; sizing; drying; sintering; pelletizing; briquetting; calcining to remove water and/or carbon dioxide; roasting, autoclaving, and/or chlorination in preparation for leaching (except where the roasting/leaching sequence produces a final or intermediate product that does not undergo further beneficiation or processing); gravity concentration; magnetic separation; electrostatic separation; flotation; ion exchange; solvent extraction; electrowinning; precipitation; amalgamation; and heap, dump, vat, tank, and in situ leaching (40 CFR 261.4(b)(7)(i)). Beneficiation operations generate high-volume/low-hazard waste streams that essentially are earthen in character. Mineral **processing** operations generally follow beneficiation and change the concentrated mineral value into a more useful chemical form. Mineral processing commonly employs heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral (Miller 2011).

Hazard index: The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. (A hazard quotient is the ratio of a single substance exposure level over a specified time period [e.g., subchronic] to a reference dose for that substance derived from a similar exposure period.) The hazard index is calculated separately for chronic, subchronic, and shorter-duration exposures. A hazard index value of 1.0 or less indicates that no adverse human health effects (noncancer) are expected to occur (EPA 1989).

Hazardous substances: Superfund's definition of a hazardous substance includes the following:

- Any element, compound, mixture, solution, or substance designated as hazardous under Section 102 of CERCLA.
- Any hazardous substance designated under Section 311(b)(2)(a) of the Clean Water Act, or any toxic pollutant listed under Section 307(a) of the CWA. More than 400 substances are designated as either hazardous or toxic under the CWA.
- Any hazardous waste having the characteristics identified or listed under section 3001 of the Resource Conservation and Recovery Act.
- Any hazardous air pollutant listed under section 112 of the Clean Air Act, as amended. Over 200 substances are listed as hazardous air pollutants under the CAA.
- Any imminently hazardous chemical substance or mixture that the EPA Administrator has "taken action under" Section 7 of the Toxic Substances Control Act.

Hazardous Waste: Hazardous waste is defined under the Resource Conservation and Recovery Act as a solid waste (or combination of solid wastes) that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may: (1) cause or contribute to an increase in mortality or an increase in serious irreversible, or incapacitating illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. In addition, under RCRA, EPA establishes four characteristics that determine whether a substance is considered hazardous, including ignitability, corrosiveness, reactivity, and toxicity. Any solid waste that exhibits one or more of these characteristics is classified as a hazardous waste under RCRA and, in turn, as a hazardous substance under Superfund.

Pollutants: For purposes of the Clean Water Act, "pollutant" means dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended [42 U.S.C. 2011 et seq.]), heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Residual radioactive material: Defined in 10 CFR 40 as: "Waste (which the Secretary of Energy determines to be radioactive) in the form of tailings resulting from the processing of ores for the extraction of uranium and other valuable constituents of the ores; and (2) other waste (which the Secretary of Energy determines to be radioactive) at a processing site which relates to such processing, including any residual stock of unprocessed ores or low-grade materials. This term in used only with respect to materials at sites subject to remediation under title I of the Uranium Mill Tailings Radiation Control Act of 1978, as amended.

Source material: Defined in 10 CFR 40 as "(1) Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of: (i) Uranium, (ii) thorium, or (iii) any combination thereof."

Supplemental standards: Standards in 40 CFR 192 Subpart C that may be permitted in lieu of standards in Subparts A or B under certain circumstances, including if "Radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials" (40 CFR 192.21(h)).

TENORM (technologically enhanced naturally occurring radioactive material): Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing. "Technologically enhanced" means that the radiological, physical, and chemical properties of the radioactive material have been altered by having been processed (beneficiated) or disturbed in a way that increases the potential for human and/or environmental exposures (EPA 2007c).

This page intentionally left blank

Appendix B

Cleanup Levels for Uranium Mine Sites

This page intentionally left blank

Site-Specific Levels	Document	Cleanup/Action Level	Basis/Exposure Scenario	Notes
Northeast Church Rock Mine	Engineering evaluation/cost analysis (EE/CA) (EPA2009a)	2.24 pCi/g radium-226 (Ra-226)	Mean background + residential Preliminary Remediation Goal (PRG) (1.24 pCi/g Ra-226)	CERCLA cleanup
Midnite Mine	Record of Decision (EPA 2006a)	43 mg/kg uranium (total) 7.5 pCi/kg lead-210 4.7 pCi/g Ra-226	Background; risk-based levels are less than background for residential and recreational use scenarios	Nonresidential risks dominated by meat/plant ingestion (near subsistence); CERCLA cleanup
White King	Record of Decision (EPA 2001)	442 mg/kg arsenic (As) 6.8 pCi/g Ra-226	Background; risk-based levels are less than background	Worker/recreational risks slightly higher than 10^{-4}; residential around 10^{-1}; arsenic is main risk-driver for nonresidential exposures; gamma/radon main residential risk drivers
Lucky Lass	Record of Decision (EPA 2001)	38 mg/kg As 3.6 pCi/g Ra-226	Background; risk-based levels are less than background	Worker/recreational risks slightly higher than 10^{-4}; residential around 10^{-1}; arsenic is main risk-driver for nonresidential exposures; gamma/radon main residential risk drivers
San Mateo Uranium Mine	EE/CA (USFS 2009)	Tables with values not included in the report	1×10^{-4} risk level; gamma exposure, 14-day camper scenario	14-day gamma exposure value from EPA TENORM report is 307 pCi/g Ra-226 for 1×10^{-4} (not clear if this is the number they used)
Quivira Mine	Action Memorandum, EPA Region 9 (EPA 2010b)	2.24 pCi/g Ra-226	Mean background + residential PRG (1.24 pCi/g Ra-226; 1×10^{-4})	
Tronox AUM Sections 32 and 33	Removal Assessment Report (EPA 2012b)	2.11 pCi/g Ra-226	Highest background (0.900 pCi/g) + residential PRG (1.21 pCi/g)	Incremental increase in dose of 15 mrem/yr above background
Juniper Uranium Mine	EE/CA (USFS 2005)	Concentration not specified; background + 12 µR/h	PRG is to reduce gamma to below 15 mrem/yr assuming 52-day exposure; human health benchmark of 0.2 pCi/g Ra-226 included in table	52-day gamma exposure value from EPA TENORM report is 83 pCi/g Ra-226 for 1×10^{-4} (not clear if this is the number they used)
Skyline Uranium Mine	Removal Assessment Report (EPA 2010c)	10.36 pCi/g Ra-226	RESRAD offsite; estimated dose for offsite residents of 5 mrem/yr	Inaccessibility of site was recognized
Cove Transfer Station	Removal Action Report (EPA 2013b)	2.1 pCi/g Ra-226	Background (0.79 pCi/g) + residential PRG (1.21 pCi/g Ra-226 for 1×10^{-4} risk)	Not a mine, but included because of similar wastes
Workman Creek Uranium Mine Sites	EE/CA (USFS 2008)	7.57 pCi/g Ra-226 for campgrounds; 67.4 pCi/g for mine areas	5 pCi/g + background; 30-day/yr recreational scenario; 1×10^{-4} incremental risk above background	Used 30-day 10^{-4} value from EPA TENORM table divided by 30 years
Riley Pass Uranium Mines	EE/CA (USFS 2006b)	3 categories identified: Category 1: ≤30 pCi/g Ra-226 Category 2: >30–50 pCi/g Ra-226 Category 3: >50 pCi/g Ra-226	EE/CA states cleanup based on 10^{-5} for recreational scenario (hunter) with ingestion of meat from the site	Different management approach for each category: Category 1: No removal of material—vegetate and stabilize Category 2: Bring average measurements down to 30 pCi/g or less by covering, removing, etc. Category 3: Excavate and place in repository; in case of coal seams exceeding criteria, seams will be covered or otherwise mitigated but not removed
King Edward Mine	EE/CA (USFS 2006a)	Does not appear that formal numerical cleanup levels were established	Used EPA PRGs for comparison—3.69 pCi/g Ra-226; assessed qualitative risks to recreational users	Recommended remediation approach is to consolidate and cap waste-rock piles to minimize exposures and erosion/leaching; the mine is located near the head of Cottonwood Wash, which has been the subject of efforts to include surface water quality
Butterfly and Burrell Mines	EE/CA (USFS 2011)	No numerical criteria established for soils, waste rock; compared metals to BLM risk management criteria for recreational scenarios	Notes that recreational use is most likely to occur	Preferred alternative involves removing physical risks; final state of site will discourage camping; wastes will be covered and contoured to prevent erosion
Cottonwood Wash, Utah	Cottonwood Wash TMDL (UDEQ 2002)	Stabilize mine waste dumps that are affecting surface water quality; close mine openings to protect the public; gross alpha TMDLs developed for different locations in the watershed	Public lands—multiple use (nonresidential)	Main driver is CWA; TMDL completed

Generic Guidance	Document	Cleanup/Action Level	Basis/Exposure Scenario	Notes
Navajo AML general approach	May 30, 2013, presentation	3 classes of materials: Class A: near natural background (around 2 pCi/g) Class B: above background but below 25 pCi/g (50 μR/h) Class C: above 25 pCi/g (>50 μR/h)		General management approach is to bury Class C followed by Class B; finish with a cover of Class A
BLM	Handbook H-3042-1: *Solid Minerals Reclamation Handbook* (BLM 1992); CERCLA Response Handbook (H-1703-1)	Not specified. Emphasis on site stabilization; control mine drainage;	Public lands—multiple use (nonresidential)	A draft revised Solid Mineral Reclamation Handbook (February 9, 2001) incorporated the UMTRCA standard of 5/15 pCi/g for radioactive mine wastes. It also notes that wastes should be covered with not less than 6 inches of soil with an upper Ra-226 limit of 5 pCi/g above background. It is further noted that 18 to 24 inches over such cover is preferable.
Colorado BLM Uranium Mine Reclamation Guidelines	Supplement to BLM Handbook H-3042-1 (BLM 1995)	Goal is to minimize radioactivity emanating from the site; mine openings with radon working level > 10 are to be sealed; bury higher radioactive material under lower or nonradioactive material	Public lands—multiple use (nonresidential)	
Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA sites	OSWER Direction No. 9200.4-25 (EPA 1998)	Discusses applicability of 5/15 pCi/g (over background) Ra-226 at CERCLA sites	Residential	Only relevant if contaminants and their distribution are similar to that at UMTRCA sites
Cleanup Levels for CERCLA Sites with Radioactive Contamination	OSWER No. 9200.4-18 (EPA 1997b)	10^{-4} to 10^{-6} risk range; 15 mrem/yr effective dose equivalent if a dose assessment is conducted (approximately equivalent to 3×10^{-4} increased lifetime risk)	CERCLA risk range; numerical goals for individual contaminants will depend on land use assumptions	
Risk Management Criteria for Metals at BLM Mining Sites	BLM Technical Note 390 (BLM 2004) (Note: BLM considers values in this publication to be outdated; document needs to be reviewed and updated)	Provides human health risk-based criteria for metals in soils, sediments and surface water for different exposure scenarios; provides standards for surface water; provides wildlife and livestock risk management criteria for metals in soils; not intended for use as cleanup standards	Based on a 10^{-5} excess cancer risk for each scenario (includes resident, camper, worker, among others)	Equations provided for calculating risk-based concentrations, but exposure assumptions not included (e.g., frequency, duration)

Notes:
As = arsenic
EE/CA = engineering evaluation/cost analysis
PRG = Preliminary Remediation Goal
Ra-226 = radium-226