2.0 GEOGRAPHIC ANALYSIS ON THE LOCATION OF URANIUM MINES

With the exception of some phosphate mine areas in central and northern Florida, people are most likely to be exposed to uranium mining-related TENORM in the western United States. This chapter provides a geographic analysis of the spatial locations of western mines in proximity to human populations, cultural and political features and boundaries, and environmental features. The use of geographical information system (GIS) software provides a systematic means to understand the potential impacts and scenarios by which humans and the environment may be impacted by uranium mines.

Figure 2.1 was generated from uranium mining-related records from the U.S. Bureau of Mines—now U.S. Geological Survey (USGS)—Mineral Availability System/Mineral Industry Location System (MAS/MILS) database from the EPA BASINS data (U.S. EPA 2001c). While about half of the 8,234 locations are documented as producing ore, the remaining records may identify mines or simply locations with uranium. Of the 8,234 records, 4,141 are categorized as "producer" or "past producer," and these terms are being used as proxies for known mines. Another 63 records are classified as mills or processing plants, and once these are removed, the 4,078 records that are left are assumed to be former mines. Of the 4,078 mines, about 3,000 are in Colorado, Utah, Arizona, and New Mexico. Similar information comes from the Department of Energy's (DOE) Energy Information Administration database (Smith 2002), which has 3,502 records for Colorado, Utah, Arizona and New Mexico. Within this set, 2,952 mines had at least some ore production (Table 2.1), similar in number to the MAS/MILS data.

Table 2-1. Mine Sizes for Four-Corners States

Of ~3,500 uranium mines in Colorado, Utah, Arizona, and New Mexico, 2,952 mines had at least some ore production.

Ore Production (Tons)	Number of Mines
<100	1,192
100–1,000	615
1,000–100,000	952
>1,000,000	5
Data withheld as confidential business information.	188
Total	**2,952**

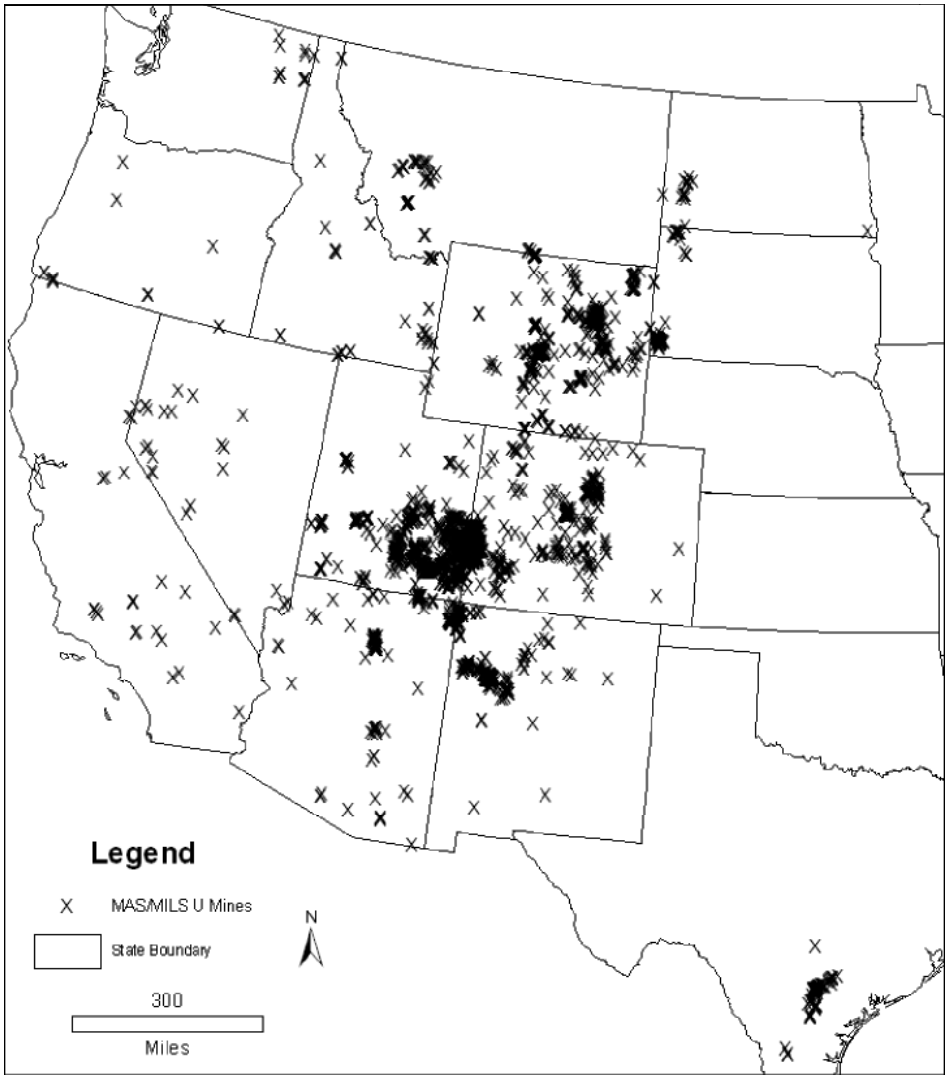
Source: Smith 2002.

The definition of a mine leads to problems with determining how many mines really exist. Even a single data set may have different interpretations for what could be considered a mine. Records may indicate multiple mine portals for an underground mine, for example. EPA has compiled a database of uranium locations from different sources totaling about 15,000 records, from which an attempt has been made to remove redundant records (U.S. EPA 2006b). The EPA database thus lists several thousand more mines than any other data set. Table 2.2 compares the number of records by state for the USGS MAS/MILS database (U.S. EPA 2001c) and unpublished USGS data sets by Finch **(**1998). The BASINS MAS/MILS database typically lists more mines than the Finch data set, although Finch has noted more mines in Texas and South

Dakota. The EPA ULD Compilation (U.S. EPA 2006b), as sorted for this analysis,[1] contains nearly 11,000 records, and typically has more uranium locations per state than the other data sets.

Figure 2-1. Mines and Other Locations with Uranium in the Western U.S.

Hundreds of active and abandoned uranium mines are scattered over wide areas of the western United States.



Source: MAS/MILS Database.

[1] For this comparison, the EPA ULD Compilation was sorted to delete the Mineral Resource Data System (MRDS) data, because many of the records were identified as simply drill holes, or mineral locations and also included many eastern locations not relevant to this study. In addition, location names that were variations on unknown or unnamed in the MINE NAME field in the ULD were removed so that the remaining records were more likely to be actual mining sites. For example, records with MINE NAME fields with entries such as "UNKNOWN," "UNKNOWN NAME," "UNNAMED PROSPECT," and "UNNAMED URANIUM OCCURRENCE" were deleted.

Table 2-2. Comparison of Data Compiled from Uranium Mine Records

Different data sets have different estimates of the number of uranium mines.

State	BASINS MAS/MILS		Finch	EPA ULD Compilation
	All Records	Producer or Past Producer		
Arizona	466	146	403	1,104
California	243	23	59	268
Colorado	2,286	1,631	1,262	2,268
Idaho	234	34	6	216
Missouri	2	0	0	2
Montana	195	47	31	482
Nevada	363	24	20	396
New Mexico	756	337	330	2,247
North Dakota	23	16	13	109
Oklahoma	2	0	8	0
Oregon	100	15	6	56
South Dakota	197	130	203	307
Texas	69	69	90	136
Utah	1,542	911	1,120	2,047
Washington	68	13	20	98
Wyoming	1,616	682	625	1,172
Totals	**8,162**	**4,078**	**4,196**	**10,908**

Sources: U.S. EPA 2006b, U.S. EPA 2001c, and Finch 1998.

2.1 Errors in Mine Locations

The mine record data used for most of the geospatial analyses, have two distinct error types. In addition to the definition of "mine" that was discussed above, there are errors of omission and commission (i.e., erroneous locations in the database, as well as actual mines not represented). However, accuracy of the data was checked in the EPA ULD compilation (U.S. EPA 2006b), and the mines were typically found to be within several hundred meters of mines identified on U.S. Geological Survey maps. The primary endpoint of the analyses described in this document is in terms of the radiation dose to an individual, not the collective dose to a population group. For this reason, errors in the total number of mines will not have a significant effect on the overall conclusions. There are also location precision errors (i.e., a listed mine not in its actual location as shown on USGS maps, for example). The latter are not likely to affect the analyses in this document because of the focus on risks to individuals, not populations.

2.2 Number of People Potentially Exposed to Uranium Mine Wastes

The 1983 EPA study found that, for releases to air and surface waters, the cancer risks were less than 10^{-4} and 10^{-6} for people living 1 mile or farther from active and inactive mines, respectively. Based on this information, we have assumed that the populations primarily at risk live within 1 mile (1.6 km) of uranium mines and, thus, have estimated the number of people within 1 mile of a uranium mine. We have also estimated the number of people who live nearby (within 5 miles

[8 km]) to help identify a likely population that may engage in recreational or other visitation activities in areas with unreclaimed uranium mines.

To estimate the number of people who live in proximity to uranium locations, we queried the 4,078 records in the MAS/MILS mine database in ArcView 8.2, ArcView 9.1, and Spatial Analyst (collectively, ArcView), using population data from the 2000 census (ESRI 2001). About 800,000 people are estimated to live within 5 miles of a uranium mine, and about 55,000 (or about 10 to 15 people per mine on average) are estimated to live within 1 mile of such a mine. About 10,000,000 people are estimated to be within 50 miles (80 km) of a recorded mine, with 502 of 4,078 mines located within 50 miles (80 km) of cities whose population is greater than 30,000. A search indicates that 33 of the recorded mines are within 1 mile (1.6 km) of a U.S. Bureau of Census "place" in the ArcView database, most of which are in Colorado; 141 of the mines are within 5 miles of a place (Table 2.3). In comparison, an analysis of the 10,908 "mine" locations from the ULD found that the population within 1 mile (1.6 km) and 5 miles (8.0 km) of a uranium location was 227,692 and 3,993,642, respectively.

The low number of people living within 1 mile (1.6 km) of a mine can be attributed to the fact that 7,076 of the MAS/MILS 8,234 records (86 percent) are located on federal land, while about 90% of the mines with known production are on federal land (Table 2.4). In the ULD data set, 8,124 of the 10,908 locations (74.5%) of the locations were on federal land (Figure 2.2 is a map of the ULD locations and federal lands). A query of the 7,076 mine records using ArcView revealed that 6,127 mines could be attributed to a specific federal land management agency, with most on U.S. Department of the Interior lands or Forest Service lands (Table 2.4). With the majority of the mines on federal land, people who use these sites for recreation would most likely be subjected to the greatest potential for exposure to uranium mine wastes. An exception to this would be the uranium mines on Tribal lands, where the Tribal members would receive the greatest exposure potential. Five percent (221) of the 4,078 mine records in the MAS/MILS database are on Bureau of Indian Affairs land, while eight percent (898) of the 10,908 records of the EPA ULD used in this analysis are on Bureau of Indian Affairs land.

Of the 69 mines in the MAS/MILS data identified in Texas, none are on federal lands. Over one half of the past-producer mines in Wyoming (456 of 682) are on federal lands. Of the 1,631 mines in the past-producer Colorado data set, 1,572 are on federal lands.

2.3 Mines by Watershed

One method used to view the potential for impact by mining on a region and to identify the most likely areas to be affected is on a watershed basis using geographic information system technology (Ferderer 1996). In Figure 2.3, uranium mines have been grouped in watersheds identified by 8-digit hydrologic unit codes (HUCs). Several watersheds have more than 100 uranium mines while a number of others have more than 50 mines. As might be expected from the discussion above, the highest watershed mine density is in Colorado, Utah, and Wyoming. In the watersheds with only a few mines, the mines typically produced uranium as a by-product of other mining, such as copper. One example is the Lefthand Creek mining area along the Front Range in Colorado where gold and silver were the primary metals mined, but also mined were tungsten, copper, fluorspar and uranium (U.S. EPA 2003b). Watersheds are also a unit considered in mine remediation (U.S. EPA 2003b, Buxton et al. 1997).

Table 2-3. Estimated Number of People within 1 Mile (1.6 km) and 5 Miles (8 km) of a Recorded Mine

The 4,078 mine records in the BASINS MAS/MILS database and 10,908 records from the EPA Uranium Location Database Compilation (U.S. EPA 2006b) were queried for the number of people near the uranium locations. Colorado accounts for most of the population living near current and past uranium mines.

State	People within 1 Mile	People within 1 Mile	People within 5 Miles	People within 5 Miles
	From 4,078 Records Using Producer or Past Producer and 2000 Census Data	***From 10,908 Records of EPA ULD and 2000 Census Data***	***From 4,078 Records Using Producer or Past Producer and 2000 Census Data***	***From 10,908 Records of EPA ULD and 2000 Census Data***
Arizona	1,045	21,727	12,160	438,581
California	1,068	34,867	59,437	758,545
Colorado	33,191	67,319	518,357	1,188,827
Idaho	494	5,399	5,803	89,486
Montana	891	5,954	8,233	89,573
Nevada	188	17,369	11,332	577,189
New Mexico	6,013	46,736	84,869	512,102
North Dakota	1,114	1,262	2,159	3,518
Oregon	370	1,134	6,162	30,894
South Dakota	2,889	2,956	5,954	8,538
Texas	591	871	11,700	32,640
Utah	1,387	7,169	22,376	106,015
Washington	162	5,144	3,472	79,200
Wyoming	5,196	9,785	61,701	78,534
Totals	**54,599**	**227,692**	**813,715**	**3,993,642**

Figure 2.4 illustrates one region of high-density uranium locations in drainages in southwest Colorado and eastern Utah. Figure 2.4 contains surface and underground mines, in addition to mines whose types are listed as "unknown" in the MAS/MILS database. This region typically has horizontal rock layers that have been incised by streams exposing the uranium-bearing layers, such as the Chinle Formation. In this figure, flat-lying areas appear generally featureless, whereas areas incised by streams show relief and appear to be v-shaped. Many of the mine locations are adjacent to streambeds where the mining has taken advantage of exposed uranium layers. The slopes along the canyon walls could enhance movement of radioactive materials to streambeds via mass-movement processes. Since radium and uranium may largely precipitate out of solution or adhere to particles and come to rest in sediments, benthic organisms may be the most potentially affected. However, large-magnitude events (e.g., flooding) could resuspend the material and move it around the streambeds, with higher concentrations likely developing in slack-water deposits where the water flow slows.

Figure 2-2. Uranium Locations from EPA Database and Federal Lands

About three-fourths of the uranium locations in the EPA Uranium Location Database are on Federal Lands. Thus, the most likely exposure or risk scenario for many of the uranium mine locations is the recreational scenario, such as hiking, camping, use of all-terrain vehicles or other short-term activity.

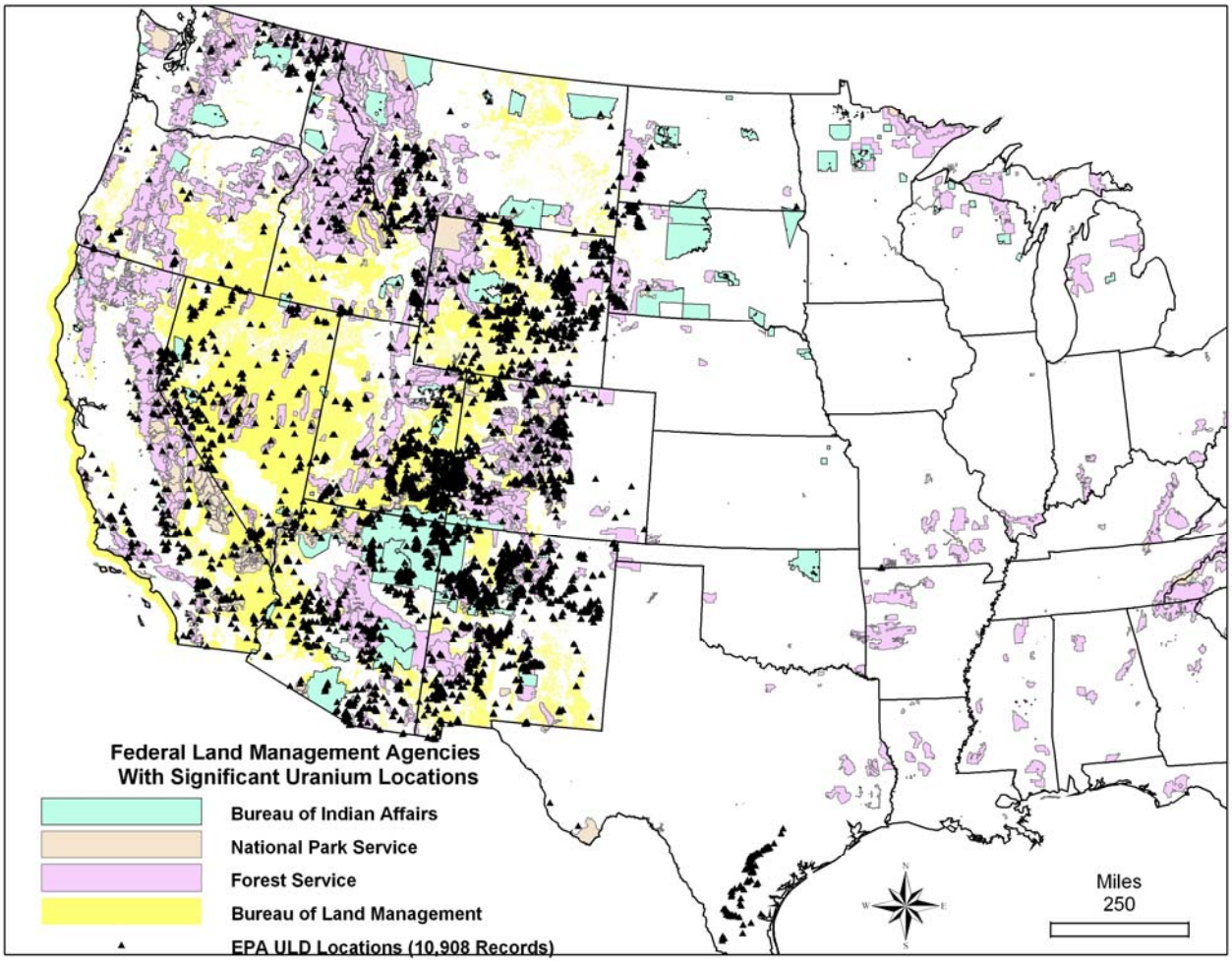


Table 2-4. Number of Mines on Federal Lands in Selected States

Most of the uranium mines on federal lands can be attributed to a specific federal land management agency; the U.S. Department of the Interior and U.S. Forest Service are the two primary land management agencies.

Federal Land Management Agency	From 8,234 Records in BASINS MAS/MILS Database	From 4,078 Records Using Producer or Past Producer and 2000 Census Data
Department of Interior		
Bureau of Land Management	4,241	2,405
Fish and Wildlife Service	7	0
Bureau of Indian Affairs	446[a]	223
National Park Service	121[b]	43
Bureau of Reclamation	3	1
Department of Defense	12	6
Forest Service (USDA)	1,297	515
Unknown	949	500
Total	**7,076**	**3,693**

a Primarily on Navajo lands.in Arizona, New Mexico, and Utah, in that order

b Primarily in Utah and California, with California primarily having unnamed prospects.

Figure 2-3. Western Uranium Mine Density by 8 Digit Hydrologic Unit Code

The greatest number of mines (745) in the MAS/MILS data is found in the Upper Dolores Watershed, located primarily in southwest Colorado with a small area in Utah. Other watersheds with more than 300 uranium mines are the Lower Dolores (Colorado and Utah) and San Miguel (Colorado) Watersheds.

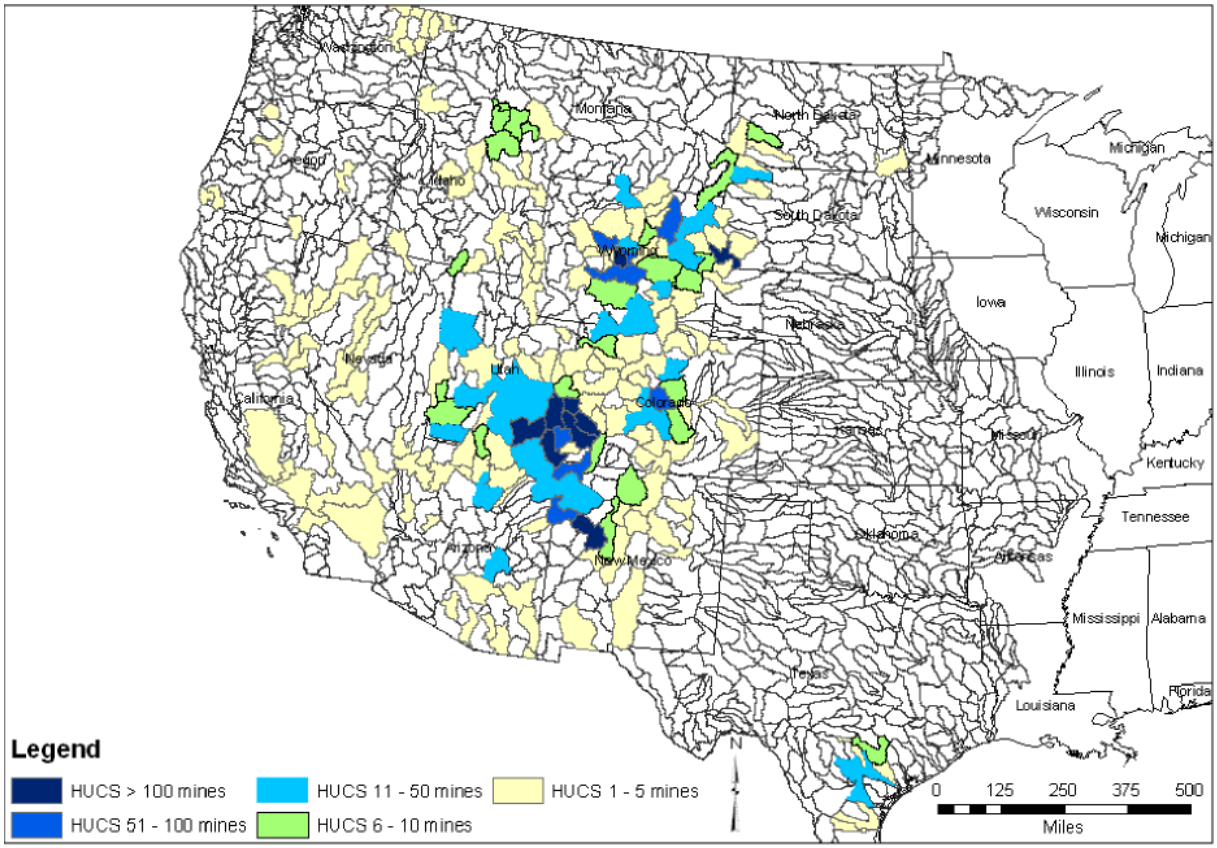


Figure 2-4. Uranium Locations in Southwest Colorado and Southeast Utah

This region typically has horizontal rock layers that have been incised by streams exposing the uranium bearing layers, such as the Chinle Formation. Flat-lying areas appear generally featureless, whereas areas incised by streams show relief and appear to be v-shaped. Many of the mine locations are adjacent to streambeds where the mining has taken advantage of exposed uranium layers. Mines from the MAS/MILS data are superimposed on digital elevation data.