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GOVERNOR'S OFFICE
OF EMERGENCY SERVICES

CALIFORNIA STATE HAZARD MITIGATION PLAN

Volume 2

Appendix R. Mineral Hazards, Vulnerability, and Risk Assessment

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Appendix R. **Mineral Hazards, Vulnerability, and Risk Assessment**

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R. MINERAL HAZARDS, VULNERABILITY, AND RISK ASSESSMENT

California has a complex and diverse geology with the potential for mineral hazards to occur statewide. It contains numerous types of rocks, which range from Quaternary to Proterozoic in age. Tectonically, it has been affected by many episodes of magmatism and metamorphism, with accompanying faulting and folding; these phenomena continue to the present. This diverse and active geologic history has resulted in a variety of potential mineral hazards throughout the State (Higgins, et al., 2016). In this appendix the term "mineral hazards" is used in a general way to include natural or earth materials that may be sources of possible environmental, human-health, or safety issues. Also included are sites of human-caused activities related to mining, prospecting, and exploration of natural resources.

Although there is no formal or legal definition of mineral hazards, for the purpose of presenting mineral hazard information in the State Hazard Mitigation Plan (SHMP), the California Geological Survey (CGS) defines mineral hazards in part as minerals, elements, and other chemical compounds that occur naturally in elevated, potentially harmful concentrations in rocks, soils, and certain fluids.

R.1. IDENTIFYING AND PROFILING MINERAL HAZARDS

The mineral hazards presented here include the group of hazards composed of naturally occurring asbestos (NOA) and other fibrous (crystals with acicular, rodlike structure) minerals, the 17 State-regulated metals and metalloids listed in the California Assessment Manual (CAM17), and the radioactive gas radon.

R.1.1. Naturally Occurring Asbestos

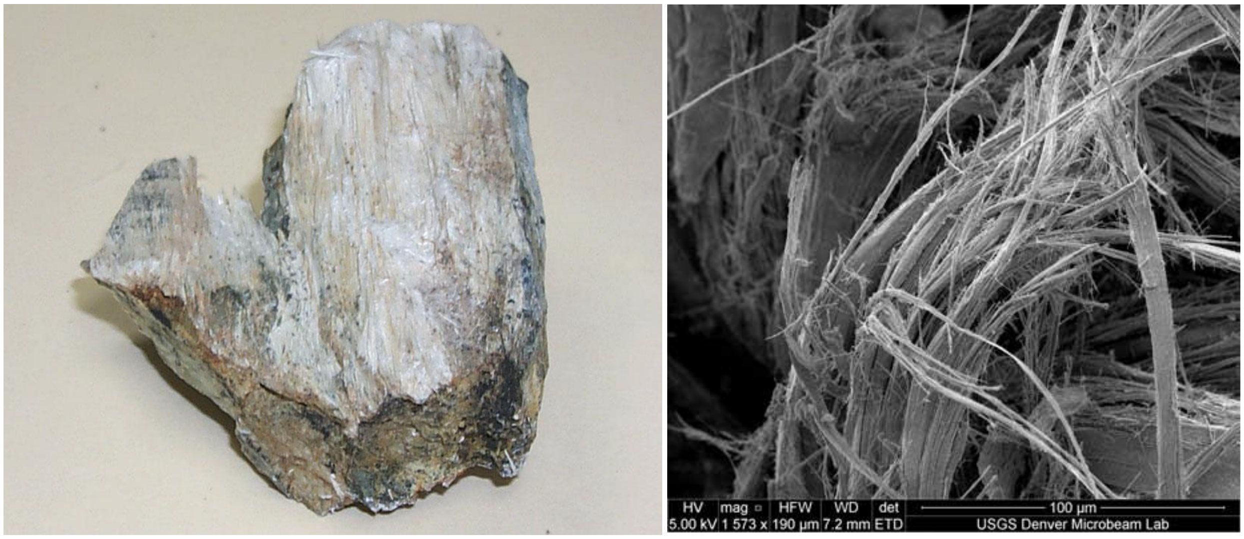
Asbestos occurs naturally in certain geologic settings in California. Most commonly, asbestos occurrences are associated with serpentinite and partially serpentinized ultramafic rocks.

Asbestos is a term used for a group of silicate minerals that occur as asbestiform fibers having high tensile strength, flexibility, and heat and chemical resistance. Asbestos is a known carcinogen and inhalation of asbestos may result in the development of lung cancer or mesothelioma. The asbestos contents of many manufactured products have been regulated in the U.S. for a number of years. For example, the California Air Resources Board (CARB) has regulated the amount of asbestos in crushed serpentinite used in surfacing applications, such as for gravel on unpaved roads, since 1990. In

1998, new concerns were raised about possible health hazards from activities that disturb rocks and soil containing asbestos and may generate asbestos-laden dust. These concerns led CARB to revise their asbestos limit for crushed serpentinite and ultramafic rock in surfacing applications from 5 percent to less than 0.25 percent, and to adopt a new rule requiring best practices dust control measures for activities that disturb rock and soil containing naturally occurring asbestos.

Medical studies have shown there is an association between certain diseases, such as asbestosis, mesothelioma, and lung cancer, and asbestos exposure. Asbestos is classified as a known human carcinogen by State, federal, and international agencies, with all six types of asbestos being considered hazardous. Specific information on the health effects of asbestos can be found in the Toxicological Profile for Asbestos by the U.S. Agency for Toxic Substances and Disease Registry.

Figure R-1. Left Photo: Tremolite-asbestos specimen from California. The white fibrous asbestos is formed within the green to blue, non-asbestiform serpentinite rock in the background (CGS photo). Right Photo: Scanning electron micrograph of fibrous erionite (USGS photo).



R.1.2. Mercury in the Environment

Mercury was mined historically in California and widely used for gold recovery at mines until about 1970. Mercury from historic mercury mines or gold mines has entered a number of watersheds in California. In some watershed environments this mercury may enter the food chain and become a health hazard to animals and humans.

Mercury is a human neurotoxin, with developing fetuses and small children at highest risk. The principal route of human exposure is through consumption of fish contaminated by mercury. Mercury occurs in various forms and compounds in the environment, some of which are not bioavailable. When mercury enters an aquatic environment, by erosion, atmospheric deposition or as the result of human activity, it may convert to methylmercury. Methylmercury is readily taken up by aquatic organisms and tends to concentrate as it moves up the food chain. This process is referred to as biomagnification and can result in high mercury concentrations in predatory fish such as striped bass and sharks, and in fish-eating birds and mammals.

Mercury is present in the environment as a result of both natural processes and human activities. Natural sources of mercury include volcanoes, hot springs, and natural mercury deposits. Sources related to human activities include coal combustion, waste incineration, certain industrial activities, and some mining activities.

Historical mining operations played two roles in California environmental mercury issues today. First, between 1846 and 1981, about 100 million kilograms of mercury were produced within the State. Second, gold mining activities that took place between 1848 and the first part of the 20th century depended upon processes that use mercury. Significant quantities of mercury were lost to the environment during both activities.

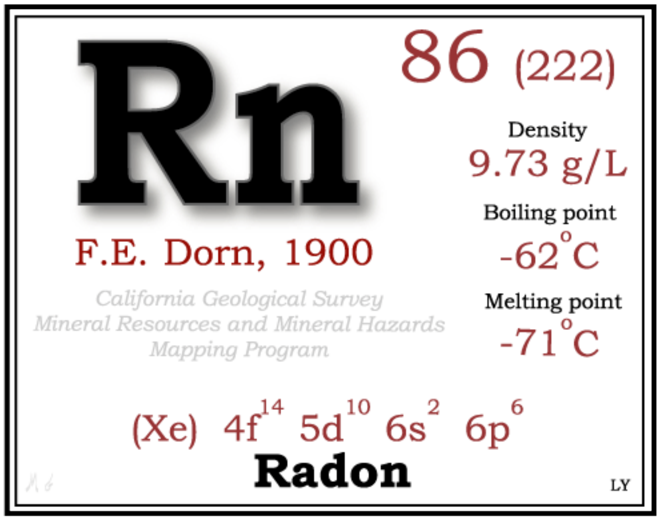
Exposure of mineral deposits and mine waste materials to air and water at mining sites and use of ore-processing chemicals at these sites are potential sources of chemical hazards both at the sites and at downstream locations. Because of both the excavation and exposure of mineralized rock and the possible processing of ore, the metal-mining districts and mineralized areas of the State may be a source of elevated concentrations of one or more CAM17 metals.

R.1.3. Indoor Radon

In its natural state, radon is an odorless, colorless radioactive gas. Breathing air with elevated levels of radon gas results in an increased risk of developing lung cancer. Not everyone exposed to radon will develop lung cancer, but the U.S. Environmental Protection Agency (EPA) and the National Cancer Institute estimate the annual number of lung cancer deaths in the United States attributable to radon is 21,000.

Figure R-2. Cinnabar. This photograph shows a cinnabar specimen from New Almaden district, Santa Clara County, California. Cinnabar is a mercury sulfide with the chemical formula HgS. It was the main ore of mercury at many California mercury mines. It is characterized by its bright red color. Mercury was recovered by heating the cinnabar and collecting and cooling the mercury vapors that were produced.

The gas forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks and soils. Some amount of radon exists in all rocks and soils, but some rock types, such as black shales and certain igneous rocks, can have uranium and thorium in amounts higher than is typical for the earth's crust. At these locations, increased amounts of radon will be generated in the subsurface. Because radon is a gas, it can easily move through soil and cracks in building slabs or basement walls and concentrate inside a building. Areas with higher amounts of radon in the underlying rocks and soil are likely to have higher percentages of buildings with indoor radon levels in excess of U.S. EPA guidelines.



Radon is the only naturally occurring radioactive gas and is the heaviest of all the elements that occur as gasses at room temperature and pressure conditions. Radon is one of several intermediate radioactive elements formed during the radioactive decay of uranium-238, uranium-235 or thorium-232 isotopes to form stable, non-radioactive isotopes of lead. Radon-222 is the radon isotope of most concern to public health because it has a much longer half-life (3.8 days) than other radon isotopes (radon-219 at 4 seconds and radon 220 at 55.3 seconds). The longer half-life of radon-222 allows it to migrate farther through the soil, so more radon-222 is usually available to enter buildings than any of the other radon isotopes.

Indoor-radon concentrations are used for determining potential exposure and for identifying buildings that require remedial action. However, it is inhalation of two radon decay products, polonium-218 and polonium-214, that most likely lead to lung cancer. These polonium isotopes have very short half-lives. When they enter the lungs, they attach to lung tissue or trapped dust particles and quickly undergo radioactive decay, emitting high-energy alpha particles that are believed to damage DNA in lung tissue cells, causing cancer (Brookins, 1990). In contrast, most longer-lived radon-222 is exhaled before undergoing radioactive decay.

The average concentration of radon in American homes is about 1.3 picocuries per liter (EPA, 2016) and the average concentration in outdoor air is about 0.4 picocuries per liter. The U.S. EPA recommends that individuals avoid long-term exposures to radon concentrations greater than 4.0 picocuries per liter. The only way to know what the radon level is in a building or home is to test the air. Fortunately, radon testing is relatively simple and inexpensive.

Figure R-3. Radon Detectors. This photograph shows two types of inexpensive indoor radon level detectors. Short-term detectors (a) use activated charcoal to adsorb radon from the air and are typically used for tests of two to seven days duration. Long-term alpha-track detectors (b) consist of a piece of special plastic inside a container. They are typically used for tests of 91 days or more. When enough collection time has passed, detectors are sent to special laboratories for analysis.

R.1.4. Other Mineral Hazards

This category includes rock units with natural background concentrations of various metals and a few elements classified as metalloids, which are listed under the term “metals”. These metals are known, or suspected, to be harmful to human health or the environment when in elevated concentrations. Included in this category are the 17 metals regulated under State law that pertains to hazardous waste materials (Title 22, Chapter 11, Article 3, Section 66261.24, Table II of the California Code of Regulations (CCR) (California Office of Administrative Law (OAL), 2015). These 17 metals are considered hazardous waste when concentrations of any of these metals equal or exceed threshold values. Equal to or greater than these values, such metals may pose significant health risks to humans or harm to the environment. As a group, these 17 metals historically have been referred to as the CAM17 list. Each metal has threshold concentration values established in the CCR, and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR 2023a) lists potential health effects of individual metals. The threshold values are placed in two categories: Soluble Threshold Limit Concentration (STLC), in milligrams per liter (mg/L), and Total Threshold Limit Concentration (TTLC), in milligrams per kilogram (mg/kg). The CAM17 metals, with their threshold limit concentrations, are shown in Table R-1

Table R-1. Threshold Values of Metals Listed in CCR Regulations Pertinent to Hazardous Waste

Metal	STLC*(mg/L)	TTLC** (mg/kg)
Antimony (Sb)	15	500
Arsenic (As)	5	500
Barium (Ba)	100	10,000
Beryllium (Be)	0.75	75
Cadmium (Cd)	1	100
Chromium (Cr)	Cr^{+3}=560; Cr^{+6}=5	Cr^{+3}=2,500; Cr^{+6}=500
Cobalt (Co)	80	8,000
Copper (Cu)	25	2,500
Lead (Pb)	5	1,000
Mercury (Hg)	0.2	20
Molybdenum (Mo)	350	3,500
Nickel (Ni)	20	2,000
Selenium (Se)	1	100
Silver (Ag)	5	500
Thallium (Tl)	7	700
Vanadium (V)	24	2,400
Zinc (Zn)	250	5,000

*STLC – soluble threshold limit concentration (amount of an analyte that is soluble as determined by a specified leachate analysis).

**TTLC – total threshold limit concentration (total concentration of an analyte in a sample).

The natural abundance of CAM17 metals in bedrock that results from “common or typical” geologic processes is referred to as “background” concentration. Background concentrations of metals within a given bedrock unit are generally (but not always) expected to fall within a “likely” range of values no matter where in the State the unit is located. This definition excludes anomalous concentrations of metals that result from rare geologic processes such as economically recoverable metals formed by hydrothermal activity or human activity. Anomalous concentrations of metals caused by human activity include current or historical industrial and agricultural activities, mine waste, placement of contaminated fill, and illegal dumping.

Some of the CAM17 metals are typically present in elevated concentrations within ore deposits and other mineralized areas within certain types of bedrock. Others can be more widely distributed as elevated background concentrations within different types or horizons of soil. These metals may also be present locally within regional areas of unconsolidated and weakly consolidated sediments, sediments along streams and dry washes, and landslide deposits. Rock types where these metals may be present are a variety of metamorphic-, igneous-, and sedimentary-rock units, particularly serpentinite and ultramafic rocks. Playas and other lacustrine deposits in the arid regions of eastern California are sometimes sources of windblown dust that may contain elements such as arsenic, which can be a health hazard. Organic-rich or phosphatic-rich metamorphosed sedimentary rocks may contain elevated amounts of cadmium, selenium, and possibly other CAM17 metals in addition to uranium, which is a radioactive element. Manganese oxides occur in the natural environment, these elements are of note because they assist the oxidation of chromium-3 to chromium-6, a toxic form.

R.2. ASSESSMENT OF MINERAL HAZARD VULNERABILITY

The impact of natural mineral hazards depends on the level of exposure of human life and the environment to the mineral. Since the 1990s, CGS has conducted many studies of mineral hazards in California in response to an increasing number of requests from government agencies, private industry, and the public. These studies have focused mostly on naturally occurring asbestos, radon, and various metals, such as mercury and cadmium. The mineral hazard maps and companion reports produced from these studies are typically at statewide and regional scales. They are designed for use by non-geoscientists and geoscientists to educate these groups about mineral hazards and to help in mitigation of those hazards. These products indicate the likelihood of the occurrence of a mineral hazard at a given location, but not the associated health risks. Information can be found on the CGS website.

R.2.1. Assessment of Asbestos Hazards

The term “asbestos” is used to identify a group of six commercially important silicate minerals that exhibit fibrous or asbestiform appearance. These minerals include the serpentine mineral chrysotile, and the amphibole minerals crocidolite (fibrous riebeckite), amosite (fibrous cummingtonite-grunerite), tremolite, actinolite, and anthophyllite. “Naturally occurring asbestos” (NOA) is the term applied to the natural geologic occurrence of any of these six types of asbestos.

Serpentine is a group of minerals (antigorite, lizardite, and chrysotile), although the same name is commonly used for the rock. Serpentinite is a metamorphic rock composed of one or more of the serpentine group minerals. In California, extensive areas of serpentinite and partially serpentinized ultramafic rock are the dominant rock types that contain NOA. Chrysotile, a member of the serpentine mineral group, is the most common asbestos mineral in California and is typically found in ultramafic rocks and their metamorphosed equivalent, serpentinite.

To a lesser extent, other geologic settings contain NOA in the form of amphibole asbestos. They are much less common in California but may be present where physical and chemical conditions were favorable for their formation. Examples include metamorphosed igneous rocks, particularly those of mafic composition, and talc deposits. Fault and shear zones in these geologic settings can also serve as favorable environments for additional concentrations of NOA. Nearly all of California's 58 counties have reported occurrences of NOA or ultramafic rock/serpentinite (Higgins, et al., 2016). Table R-2 lists NOA and other fibrous minerals. Figure R-4 is a photograph of serpentinite occurrence in a fault.

Table R-2. NOA and Other Fibrous Minerals

NOA includes:	Other fibrous minerals include:
Chrysotile (a serpentine mineral)	Erionite (a zeolite)
Asbestiform amphibole minerals: Actinolite Amosite (cummingtonite-grunerite) Anthophyllite Crocidolite (riebeckite) Tremolite	Mordenite (a zeolite) Glaucophane (an amphibole) Winchite (an amphibole) Richterite (an amphibole)

Figure R-4. Serpentinite in a Fault Along US Highway 101 (Chris T. Higgins photo)

The regulation of asbestos initially resulted from concern over the health and safety of workers subject to occupational exposure to asbestos. The industries involved with the mining, milling, manufacturing, and installation of asbestos products were the focus of this initial concern.

A discussion of the requirements for worker health and safety related to potential exposure to asbestos (U.S. Department of Labor, 1995, CFR, Title 29--Labor, parts 1900-1910) is beyond the scope of this document. In California, the California Department of Industrial Relations, Division of Occupational Safety and Health (DOSH, or Cal/OSHA) administer these regulations.

CGS provides information on the geology of asbestos occurrences in California, and has developed Guidelines for Geologic Investigations of Naturally Occurring Asbestos in California (PDF) to assist geologists conducting investigations related to NOA.

Examples of CGS asbestos hazards projects include:

- Assisting the U.S. Geological Survey (USGS) with a research program to evaluate the feasibility of using AVRIS data for identifying areas containing naturally occurring asbestos (currently in progress).
- Development of a generalized map of areas more likely to contain asbestos in California.
- Undertaking a pilot mapping project to produce a map of areas more likely to contain asbestos for El Dorado County.
- Participation on the El Dorado County asbestos committee and contributing to that committee's White Paper and Final Report.

CGS Asbestos Reports, Maps, and Guidelines for Geologic Investigations

- Map Sheet 59: Reported Historic Asbestos Mines, Historic Asbestos Prospects, and other Natural Occurrences of Asbestos in California (PDF; 79 MB)
- Map Sheet 59 – Pamphlet (PDF; 3 MB)
- Asbestos Sites (PDF) and Asbestos Sites (Excel)
- Death Valley Talc (PDF) and Death Valley Talc (Excel)
- Fibrous Amphiboles (PDF) and Fibrous Amphiboles (Excel)
- Asbestos References (PDF) and Asbestos References (Excel)

- Special Report 190: Relative Likelihood for the Presence of Naturally Occurring Asbestos in Placer County, California
- Special Report 192: Relative Likelihood for the Presence of Naturally Occurring Asbestos in Eastern Sacramento County, California
- Geologic Hazards Investigation 2004-01: Preliminary Report on Using Imaging Spectroscopy to Map Ultramafic Rocks, Serpentinites, and Tremolite-Actinolite-Bearing Rocks in California
- Special Publication 124: Guidelines for Geologic Investigations of Naturally Occurring Asbestos in California (PDF).
- Open-File Report 2000-19: A General Location Guide for Ultramafic Rocks in California – Areas More Likely to Contain Naturally Occurring Asbestos, 2000, Map scale 1:1,100,000 (PDF).
- Open File Report 2000-02: Areas More Likely to Contain Natural Occurrences of Asbestos in Western El Dorado County, California, 2000

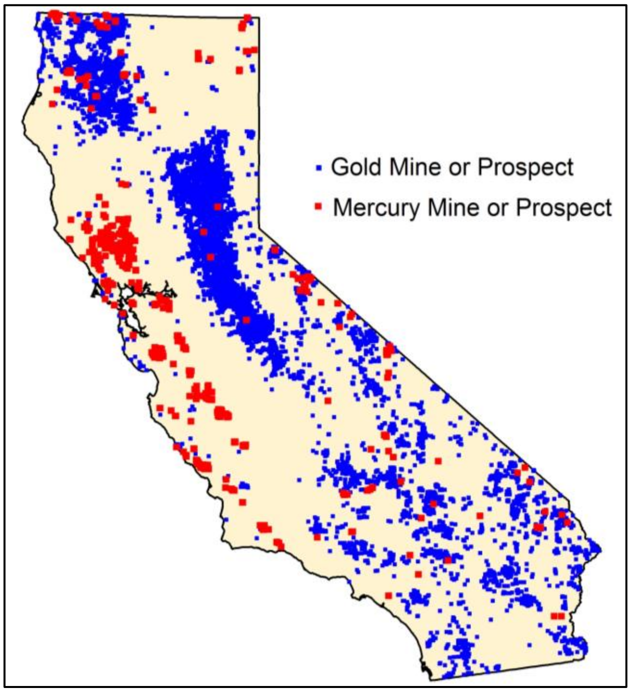
R.2.2. Assessment of Mercury Hazards

Mercury is a human health concern because it is a neurotoxin. Human exposure to organic mercury can result in long-lasting health effects, especially if it occurs during fetal development. In addition, scientists have linked mercury poisoning to nervous system, kidney and liver damage, and impaired childhood development. Nervous system disorders that can develop include impaired vision, speech, hearing, and coordination.

Mercury is present in elevated concentrations in many parts of California. Ore deposits of mercury are common in the western part of the State and many of these deposits have been mined. Some of this mercury was shipped to gold mines in other parts of the State for amalgamation. During this ore-processing, some of the mercury was lost and migrated into watersheds. In certain environments, this lost mercury is converted by sulfate-reducing bacteria into a particularly toxic organic compound called methylmercury. The methylmercury is ingested by aquatic organisms and the concentration increases higher in the food chain through a process known as biomagnification. Exposure to methylmercury by humans is predominately through the consumption of fish. Although humans can take in organic mercury through the lungs, mouth or skin, the most likely source of organic mercury in humans is eating contaminated fish and shellfish.

There are six main types of ore-processing known to be associated with mining of metal-bearing ores in California. Because of the use of mercury, the two ore-processing types of most concern are those of amalgamation (use of mercury to recover gold and silver) and distillation (use of heat to recover mercury), which was used at numerous gold mines throughout the State. Figure R-5 shows the location of mercury mines and prospects in California.

Figure R-5. Location of mercury mines or prospects (red dots) where mercury concentrations can be elevated naturally or due to mercury mining, and locations of gold mines or prospects (blue dots) where mercury concentrations can be elevated due to mercury amalgamation of gold.



Amalgamation: This process has been used in California since the 1800’s. The main reagent, mercury, is considered a potential hazard today. Although attempts were made to recover spent mercury, some of it was lost at many mine sites, which has impacted associated wetlands and watersheds.

Distillation (Retorting/Roasting): First known to be used in California in the mid-1840’s at the New Almaden Mine in Santa Clara County, this process involves heating, or “burning,” the ore to volatilize the mercury, which is then recovered by condensation. Because of the inefficiency of this process, much mercury was lost to the atmosphere or left behind as globules at retort and furnace sites. This residue would either remain on the ground surface or migrate downward into the underlying soil.

Exposure of mineral deposits and mine waste materials to air and water at mining sites, and the use of ore-processing chemicals at these sites are potential sources of chemical hazards both at the sites and at downstream locations.

CGS participated with other State and federal government agencies and university research groups in a three-year CALFED research project titled, "An Assessment of Ecological and Human Health Impacts of Mercury in the Bay Delta Watershed." This research project was completed in 2003.

In the research project, CGS was responsible for Task 5C1, "Assessment of the Feasibility of Remediation of Mercury Mine Sources in the Cache Creek Watershed." The CGS study investigated mine sites in the Sulphur Creek mining district within the Cache Creek watershed. It identified the mine site materials present at each site and estimated their volumes and mercury contents and estimated offsite mercury transport. The study also estimated regional mercury background concentrations and contributions from background and other non-mine site mercury sources to the Cache Creek watershed mercury loads.

Additional information about the report and mercury in the environment can be found on the CGS website.

R.2.3. Assessment of Radon Hazards

Radon is a naturally occurring radioactive gas that is invisible, tasteless, and odorless. It forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks and soils. Small but varying amounts of uranium are present in all rocks and soil; consequently, radon is naturally present everywhere in the environment, in rock, soil, water, and air. Radon concentrations within these materials can vary significantly. Some rock types, such as organic-rich shales, some granitic rocks, and silica-rich volcanic rocks, may have uranium and thorium in concentrations greater than is typical for the earth's crust. At these locations, increased amounts of radon will be generated in the subsurface. Because of the diverse and complex geology of the State, there are areas, mostly associated with certain sedimentary and granitic rocks in the central and southern parts of the State, that may have a greater potential for elevated radon concentrations (Higgins, et al., 2016).

Outdoor air generally has lower radon concentrations because radon entering the atmosphere from rock, soil, and water is rapidly diluted. Radon can, however, become concentrated, sometimes to high levels, in air in enclosed spaces such as building, mines, and caves. Long-term exposure to air with elevated radon concentrations increases an individual's lung-cancer risk. Radon is the number one cause of lung cancer among non-smokers, according to U.S. EPA estimates. Overall, radon is the second leading cause of lung cancer. According to the U.S. EPA, radon is responsible for about 21,000 lung cancer deaths every year.

Because radon is a gas, it can easily move through rock and soil and cracks in building slabs or basement walls and concentrate inside a building. The presence of radon can only be detected by chemical or radiation-measuring techniques. Areas with higher amounts of radon in the underlying rocks and soil are likely to have higher percentages of buildings with elevated indoor radon levels. Indoor-radon concentrations are typically higher in ground-floor rooms, and highest in basements, where air circulation if often poor. Homes with basements tend to have increased incidence of indoor-radon concentrations exceeding the U.S. EPA action level of 4.0 picocuries per liter.

Radon gas readily moves through rock and soil along micro-fractures and interconnected pore spaces between mineral grains. Radon can also enter a building in water from private wells. All groundwater contains some dissolved radon gas. The travel time of water from an aquifer to a home supplied by a private well is usually too short for much radon decay, so radon is available to be released in the house during water usage, for example through use of a bathroom shower. However, normal water usage typically adds only about 1.0 picocuries per liter of radon to indoor air per 10,000 picocuries per liter of radon in water (Grammer and Burkhart, 2004).

The average indoor-radon concentration in American homes is about 1.3 picocuries per liter (EPA, 2016) and the average outdoor air radon concentration is about 0.4 picocuries per liter. The U.S. EPA recommends that individuals avoid long-term exposures to radon concentrations greater than 4.0 picocuries per liter. The following U.S. EPA and California Department of Public Health (CDPH) websites have more information about radon, related health issues, testing, and remediation:

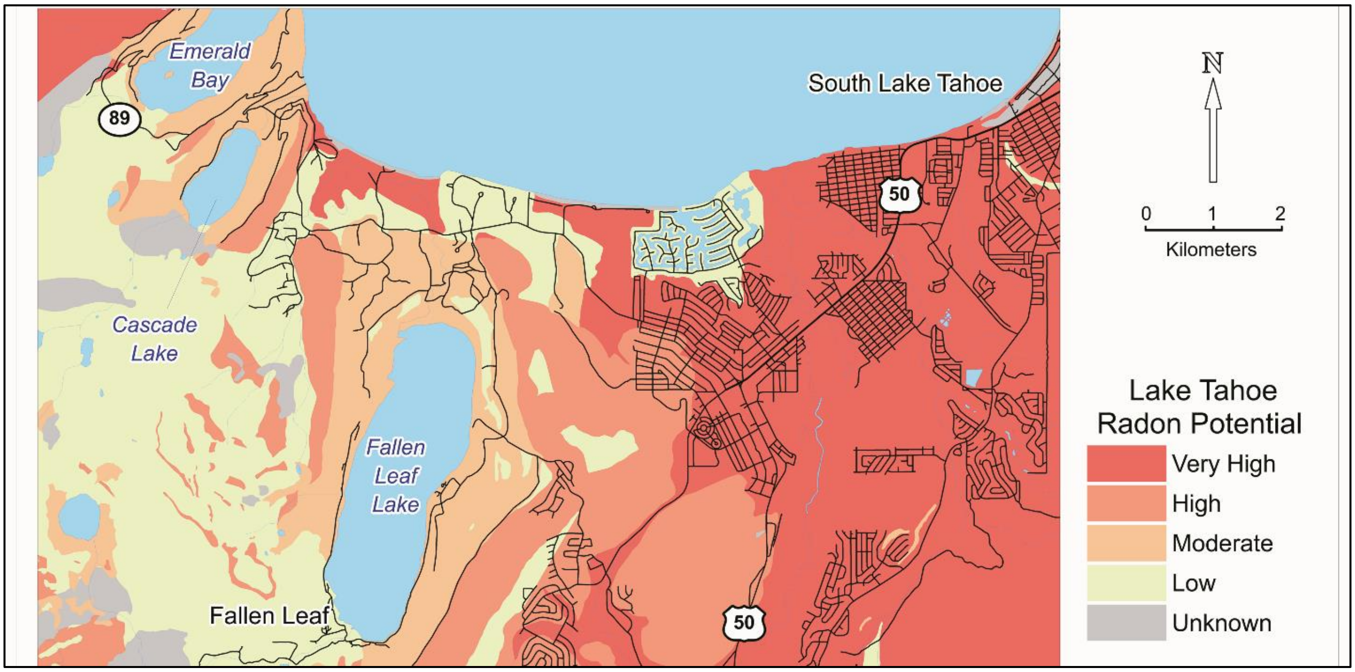
- https://www.epa.gov/radon
- https://www.epa.gov/sites/default/files/2016-12/documents/2016_a_citizens_guide_to_radon.pdf
  https://www.cdph.ca.gov/Programs/CEH/DRSEM/Pages/EMB/Radon/Radon.aspx

The California Department of Public Health Indoor Radon Program

The California Department of Public Health (CDPH) Indoor Radon Program collects radon test data for buildings throughout the State and maintains a radon database of test results.

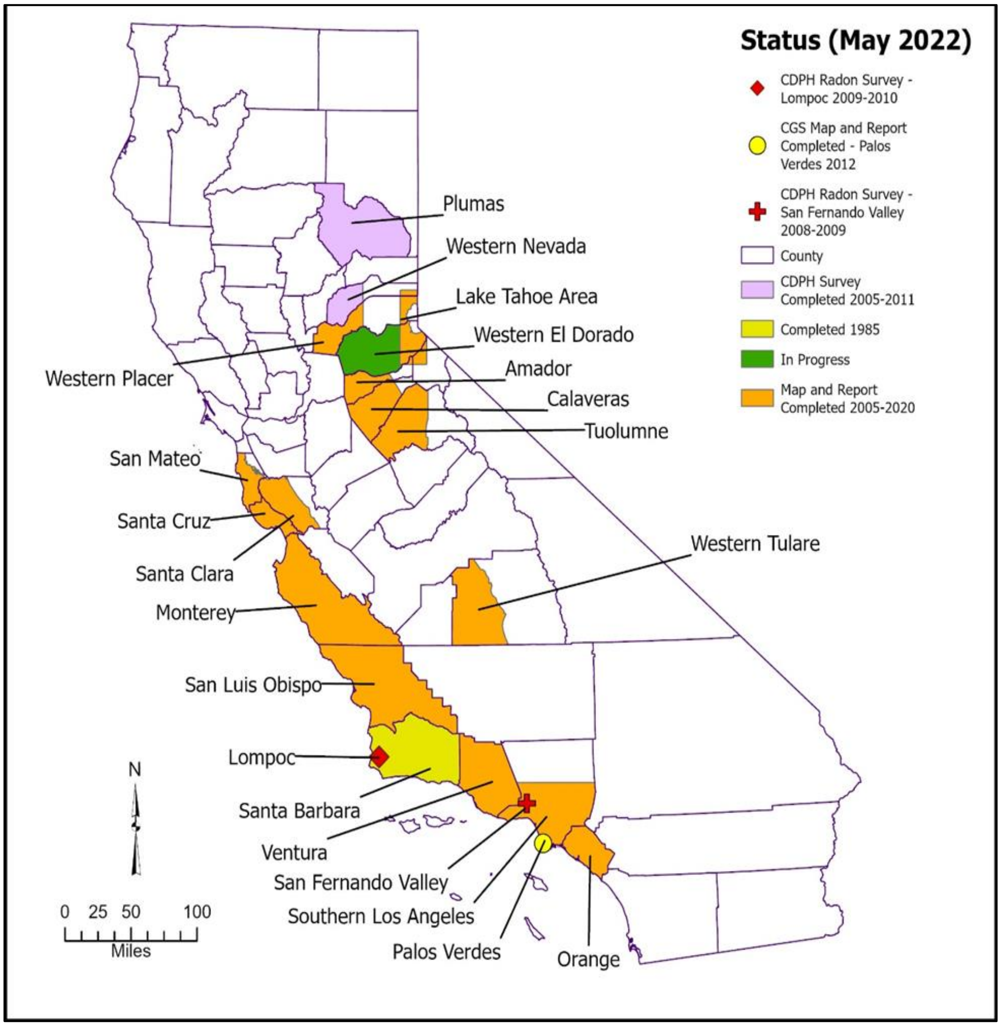
CDPH uses this database to identify areas with excessive indoor radon levels, areas that may need testing, and to inform the public of the results. Maps that accurately predict indoor-radon concentrations in specific homes and buildings are not possible because comprehensive characterization of the many variables involved is impossible. Development of maps that show "radon potential" is possible. Radon-potential maps identify areas where geologic and soil characteristics are more likely to cause buildings to exceed the U.S. EPA radon action level. CGS prepares radon-potential maps and reports to identify areas with indoor-radon potential. These maps and reports help the CDPH Indoor Radon Program serve the public and manage the health risks of indoor radon. Figure R-6 illustrates the radon potential of the Lake Tahoe area. Figure R-7 shows the status of CGS radon-potential mapping in California. The maps and reports, as well as an interactive indoor radon potential web map, are available on the CGS website.

Figure R-6. Lake Tahoe Radon Potential



Source: (CGS 2009)

Figure R-7. Status of Radon Program Surveys and CGS Radon Mapping



Source: (California Department of Conservation n.d.)

Radon Maps and Reports

Links are available on the CGS website to the following maps and reports:

- Indoor Radon Potential interactive web map – This map shows areas in California where CGS has completed studies for indoor radon potential
- Geologic Controls on the Distribution of Radon in California, 1991
- Radon Mapping in Santa Barbara and Ventura Counties, article from Nov/Dec 1997 California Geology magazine
- Radon Zone Map for Santa Barbara County
- Special Report 182: Radon Potential in Southern Los Angeles County

- SR 182, Plate 1: Radon Potential Zone Map for Southern Los Angeles County, California
- Special Report 194: Radon Potential in Ventura County, California
- SR 194, Plate 1: Radon Potential Zone Map for Ventura County, California
- Special Report 201: Radon Potential in Monterey County, California
- SR 201, Plate 1: Radon Potential Zone Map for Western Monterey County, California
- SR 201, Plate 2: Radon Potential Zone Map for Eastern Monterey County, California
- Special Report 208: Radon Potential in San Luis Obispo County, California
- SR 208, Plate 1: Radon Potential Zone Map for Western San Luis Obispo County, California
- SR 208, Plate 2: Radon Potential Zone Map for Eastern San Luis Obispo County, California
- Special Report 211: Radon Potential in the Lake Tahoe Area, California
- SR 211, Plate 1: Radon Potential Zone Map for the Lake Tahoe Area, California
- Special Report 216: Radon Potential in Santa Cruz County, California
- SR 216, Plate 1: Radon Potential Zone Map for Santa Cruz County, California
- Special Report 224: Radon Potential in the Palos Verdes Area, California
- SR 224, Plate 1: Radon Potential Zone Map for Palos Verdes Area, California
- Special Report 226: Radon Potential in San Mateo County, California
- SR 226, Plate 1: Radon Potential Zone Map for San Mateo County, California
- Special Report 232: Radon Potential in Orange County, California
- SR 232, Plate 1: Radon Potential Zone Map for Orange County, California
- Special Report 238: Radon Potential in Western Tulare County, California
- SR 238, Plate 1: Radon Potential Zone Map for Western Tulare County, California
- Special Report 242: Radon Potential in Amador, Calaveras and Tuolumne Counties, California
- SR 242, Plate 1: Radon Potential Zone Map for Amador, Calaveras and Tuolumne Counties, California

- Special Report 244: Radon Potential in Western Santa Clara County, California
- SR 244, Plate 1: Radon Potential Zone Map for Western Santa Clara County, California
- Special Report 246: Radon Potential in Western Placer County, California
- SR 246, Plate 1: Radon Potential Zone Map for Western Placer County, California

R.2.4. Assessment of Other Mineral Hazards

Some rock units in California have naturally elevated background concentrations of metals that may, in places, be high enough to be of concern. Examples include cadmium and selenium in certain organic- and phosphate-rich marine sedimentary rocks of the Coast Ranges. Such rock was found to be the primary source of selenium that was ultimately transported to a wildlife refuge where it caused deformities in waterfowl. The State is also host to thousands of metallic mineral deposits, particularly in its widespread igneous and metamorphic terranes. Although these deposits are dominantly small to medium in size, many contain high concentrations of sulfide minerals. Those in areas of temperate to humid climates have potential for acid rock drainage, which may affect groundwater or surface waters and mobilize elements of environmental concern.

The risk assessment of mineral hazards involves examining issues related to specific minerals, including environmental fate and transport, determining if sampling is sufficient to characterize contaminants and assessing the exposure of human and environmental receptors.

Current Mineral Hazard Mitigation Efforts

Site-specific environmental and ecological risk assessments are necessary to determine the appropriate mineral hazard mitigation required. These evaluations should consider the site-specific conditions and intended land use.

A preliminary endangerment assessment (PEA) is the first step in determining if the release or natural presence of a hazardous substance presents a risk to human health or the environment. The PEA begins with a human health and ecological screening evaluations. More information can be found on the California Department of Toxic Substances Control (DTSC) and California Regional Water Quality Control Boards (RWQCB) websites.

R.2.5. Mitigation of Naturally Occurring Asbestos Hazards

Asbestos emissions in California are regulated at the federal, State, and local levels. In addition to the six regulated asbestos minerals, many other minerals sometimes crystallize in the fibrous habit. Examples include brucite, antigorite, erionite, talc, tourmaline, and winchite.

The regulated asbestos minerals and erionite are known carcinogens, while asbestos also causes asbestosis, a disease of the lungs (U.S. Agency for Toxic Substances and Disease Registry, 2001). Erionite is a known carcinogen although it is not regulated at this time. CARB has implemented regulations to protect the public from exposure to NOA (CARB 2023). Specific regulations apply to dust emissions from various activities, such as construction, excavation, and mining, as well as restricting the use of NOA-bearing aggregate for surfacing applications, such as on unpaved roads. These regulations are enforced by State and local agencies.

Because exposure to airborne asbestos may cause certain diseases (e.g., lung cancer, mesothelioma, asbestosis), NOA is regulated by CARB. Regulations are intended to protect public health and safety through proper monitoring and practices. Issues related to NOA are important for several reasons including, but not limited to, compliance with regulations, worker and public safety, disposal of hazardous materials, and public relations. Laboratory testing is necessary to verify the presence of NOA.

Separately, DTSC has published Interim Guidance for Naturally Occurring Asbestos at School Sites which provides strategies for environmental assessment, investigation, mitigation, and long-term maintenance at school sites where NOA is of concern.

R.2.6. Mitigation of Mercury Hazards

DTSC is responsible for the oversight and hazard assessment of mine and prospect sites. The following information about hazard assessment is excerpted from the DTSC website:

- The hazard assessment typically begins with a site investigation (a preliminary endangerment assessment) to determine the nature and extent of contamination resulting from past mining activities. This includes identifying:
    - Hazardous substances such as arsenic, mercury, lead, and other metals, and acid mine drainage.
    - Sources such as mill tailings, waste rock, and milling and processing areas.

    - Affected media and pathways, such as soil and sediments, surface water, groundwater, and air.
    - Potential human and ecological receptors.
- Remediation options vary depending on the extent, volume, and concentration of the hazardous substance; the affected media and pathway; and the threat to humans and the environment based on the current or future land use (e.g., recreational, commercial, or residential use). Typical remedies used to address sites include source removal, encapsulation, and treatment. Because of site variables, the cost and length of remediation can vary widely. Remedies involving water treatment and waste encapsulation require long-term, often indefinite, operation and maintenance activities. Remedies are often supplemented by institutional controls that minimize the potential for human exposure. These controls include administrative or legal controls, such as land use covenants, which restrict land uses; and soil management plans, which describe how affected soil and mine waste are to be managed on sites.

The Abandoned Mine Lands Site Discovery Process explains how abandoned mine land (AML) sites are identified and brought under DTSC's and the AML Initiative Team's oversight.

The Abandoned Mine Lands Preliminary Assessment Handbook provides guidance for conducting site assessments for AML.

R.2.7. Mitigation of Radon Hazards

The only way to know what the radon level is in a building or home is to test the air. Homes can be tested for radon using inexpensive and easy to use test kits, or by hiring a certified radon tester to measure the radon concentration in the home. The most common indoor-radon testing methods utilize either charcoal (for 2- to 3-day short-term tests) or alpha-track type detectors (for 90-day to one-year long tests). These tests are simple to perform, inexpensive, and homeowners can do this testing. To perform the test, homeowners expose the radon detector following manufacturer instructions and then mail it to a laboratory for analysis, which is included in the detector cost. The CDPH Indoor Radon Program maintains lists of currently certified radon testers, mitigators, and laboratories on its website:

- https://www.cdph.ca.gov/Programs/CEH/DRSEM/Pages/EMB/Radon/Certified-Radon-Services-Providers.aspx

Radon mitigation can range from simple to complex. Passive or forced air ventilation may work to reduce radon levels in many instances; other more complex and more expensive methods of ventilation (i.e., sub-slab suction and wall-in-pipe or baseboard drains) may be necessary to reduce radon levels to acceptable limits (Brookins, 1990). Those considering new home construction, particularly at sites within a moderate or high radon potential zone, should consider radon resistant new construction practices. Post construction radon mitigation is possible, if necessary, but will be more expensive than the cost of adding radon reducing features during construction. Solutions for reducing indoor-radon levels by installing depressurization systems are described on the CDPH website:

- https://www.cdph.ca.gov/Programs/CEH/DRSEM/Pages/EMB/Radon/Radon-Fix.aspx

R.2.8. Mitigation of Other Mineral Hazards

The DTSC Site Mitigation and Restoration Program and the nine California RWQCB Site Cleanup Program are the public agencies with the legal authority and responsibility for oversight and assessment of sites where recent or historical hazardous substance releases have occurred. Because the various methods for cleanup and abatement are site dependent no specific methods will be discussed in this document.