



# Grand Canyon at Risk

Uranium Mining Doesn't Belong  
Near Our National Treasures



# Grand Canyon at Risk

Uranium Mining Doesn't Belong  
Near Our National Treasures

Environment Virginia

Rob Kerth, Jordan Schneider,  
and Elizabeth Ridlington,  
Frontier Group

Anna Aurilio,  
Environment America  
Research & Policy Center

Summer 2011

# Acknowledgments

The authors wish to thank Lauren Pagel, Legislative Coordinator with Earthworks, and Dusty Horwitt, Senior Counsel with Environmental Working Group, for their insightful comments on drafts of this report. Thanks also to Tony Dutzik and Travis Madsen of Frontier Group for editorial assistance.

The authors bear responsibility for any factual errors. The recommendations are those of Environment Virginia. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

© 2011 Environment Virginia

We all want clean air, clean water and open spaces. But it takes independent research and tough-minded advocacy to win concrete results for our environment, especially when powerful interests stand in the way of environmental progress. That's the idea behind Environment Virginia. We focus exclusively on protecting Virginia's air, water and open spaces. We speak out and take action at the local, state and national levels to improve the quality of our environment and our lives. For more information or to download additional copies of this report, please visit [www.environmentvirginia.org](http://www.environmentvirginia.org).

Frontier Group conducts independent research and policy analysis to support a cleaner, healthier and more democratic society. Our mission is to inject accurate information and compelling ideas into public policy debates at the local, state and federal levels. For more information about Frontier Group, please visit [www.frontiergroup.org](http://www.frontiergroup.org).

Cover photo: Robin Silver Photography  
Design and Layout: Harriet Eckstein Graphic Design

# Table of Contents

Executive Summary	1
Introduction	4
The Grand Canyon Is a Uniquely Valuable Natural Place	5
Mining Has Competed with Tourism for Use of the Grand Canyon	7
Uranium Mining Is a Dirty, High-Risk Activity	10
Uranium Mining Involves Dangerous Substances	10
Mining Damages the Environment	11
Each Uranium Mining and Processing Technique Poses Risks	13
Uranium Mining Has a Track Record of Environmental Contamination	14
Arizona: Fouled Streams, Damaged Aquifers, and Toxic Dirt Piles	15
New Mexico: A Giant Spill and an Ongoing Cleanup	17
The Atlas Mill at Moab: 16 Million Tons of Radioactive Rubble	18
Colorado: Poisoned Well Water and Sick Residents	19
Policy Recommendations	21
Notes	23



# Executive Summary

Uranium mining—which often requires vast open pits, spreads radioactive dust through the air, and leaks radioactivity and toxic chemicals into the environment—is among the riskiest industrial activities in the world. Every uranium mine ever operated in the United States has required some degree of toxic waste cleanup, and the worst have sickened dozens of people, contaminated miles of rivers and streams, and required the cleanup of hundreds of acres of land.

After several decades of reduced activity due to depressed prices, uranium mining is making a comeback—including on the edges of one of our nation’s most treasured wild places, the Grand Canyon.

Uranium mining has left a toxic trail across the West—including at the Grand Canyon itself. To protect this national treasure, and the millions of people who visit it each year, mining should be prohibited on land near Grand Canyon National Park, and other treasured places.

**Uranium mining is risky for miners, local residents and the environment.** Mines can release uranium itself—a dangerous radioactive substance—or toxic chemicals used in the mining process.

- **Contaminated water** can leak from mines or tailings piles, potentially entering groundwater or nearby streams and transporting contamination away from the mine. Contaminated water that enters municipal water supplies can threaten the health of large numbers of people. Mining near the Colorado River, which flows through the Grand Canyon, threatens the drinking water supplies of millions of people in cities like Phoenix, Los Angeles, and Las Vegas.
- **Airborne uranium dust** threatens the health of miners and nearby residents; if inhaled, it can cause lung cancer.
- **Tailings** – the waste rock and dirt left over once uranium extraction and milling are complete—are 85 percent as radioactive on average as the original ore and contain other toxic chemicals such as arsenic. Tailings piles can make mine sites permanently hazardous and leach toxic substances into the environment.

**Uranium mining and processing has left a toxic trail across the West—including at the Grand Canyon itself.**

- Four streams in **Arizona's** Grand Canyon National Park suffer from some degree of uranium contamination after mining activity occurred in the area.
- In **New Mexico**, a 1979 dam break released radioactive wastewater from a New Mexico uranium mill into the Little Colorado River, releasing more radiation than was released in the Three Mile Island nuclear power plant accident into downstream waterways.
- In **Utah**, workers are still cleaning up 16 million tons of contaminated tailings at the site of one of the nation's first mines in Moab.
- In **Colorado**, residents of Lincoln Park, a small community near a uranium mill, have had to stop drinking well water because of contamination from the mill's old tailings pools, and suffered health consequences from uranium and other toxic substances in their water.

**Grand Canyon National Park is a uniquely valuable place and ecosystem.**

- The Grand Canyon is a unique natural wonder—one of the world's deepest and widest canyons, home to spectacular views, great biological diversity, and a unique geologic record.
- 4.2 million people visit Grand Canyon National Park every year, making it the second most visited park in the National Park System, and the most visited park west of the Mississippi.
- Tourism to Grand Canyon National

Park contributes \$686 million to Northern Arizona's economy every year, supporting nearly 12,000 jobs.

- The Colorado River, which provides drinking water for 25 million people downstream, runs through the Grand Canyon and draws water from the area's springs and streams.

**Uranium mining is incompatible with the preservation of the Grand Canyon as a treasured ecosystem and natural wonder. The Obama administration should act to protect the Grand Canyon from the threat of uranium mining.**

- **Extend the moratorium on new mining claims near the Grand Canyon.** In June of 2011, Interior Secretary Ken Salazar extended a moratorium on new mining claims near the canyon—in place since 2009—through December 2011. The Obama administration should finalize its preferred alternative and ban new claims within a one million acre area near the canyon for the next 20 years, while pursuing permanent protection.
- **Reform mining laws to allow regulators to deny permission to mine where significant natural places or human health are at risk.** The 1872 General Mining Law, which currently governs mining on federal land through a very limited permitting process, is too lax in granting mining companies the right to stake and develop claims. Most federal land is considered open for mining by default, and regulators lack sufficient power to weigh the costs and benefits of mining against other possible uses of the land. Mining should be placed on an even footing with recreation and other land uses by allowing regulators to make a

balanced evaluation of the best use of federal lands.

- **Require uranium mining companies to clean up contamination.** Uranium companies should be required to post enough money to cover the full cost of reclamation at mine and mill sites before beginning operations. Costs

should cover all foreseeable reclamation activities, as well as insurance against accidents that would significantly raise cleanup costs. Additionally, companies should not be allowed to place mines on “standby” without cleaning them up sufficiently to prevent the spread of contamination.

# Introduction

The hike from the Grand Canyon National Park headquarters to the Hermit's Rest Overlook is one of the most beautiful in America. Incredible views greet hikers the entire way as the trail hugs the canyon's rim, looking out over the massive gorge down to the Colorado River.

At one point, however, the trail cuts away from the canyon. There, behind a rusty fence, sits the remnants of what was once one of the nation's biggest sources of uranium, the Orphan Mine. After sitting abandoned for decades, the mine's buildings were recently removed, but the ground around the site remains too contaminated for visitors to enter.

Hiking down from Hermit's Rest into the canyon, hikers can turn onto the Tonto Trail, a popular hiking trail that runs right through the middle of the canyon. Towering limestone walls line the right side of the trail, while the Colorado River passes by 1,000 feet below and to the left. Hikers using the Tonto trail fill their water bottles from creeks that spill down from springs in the canyon walls to eventually join up with the Colorado. They don't, however, drink from Horn Creek, which emerges from the rock near the site of the Orphan

Mine—the creek is too contaminated with uranium.

Most Americans do not think of Grand Canyon National Park as a mining site. Yet, for years, uranium was mined within the park's borders—leaving scars that will remain for years to come.

The Grand Canyon is not the only place in the West scarred by uranium mining. Indeed, uranium mines and processing facilities have left a toxic trail across the West—harming both the natural environment and human health.

With rising uranium prices driving mining companies to pursue the resumption of mining activity in the West, it is a good time to review the toxic legacy of uranium mining. That legacy demonstrates that uranium mining is utterly incompatible with the preservation of the Grand Canyon as a healthy ecosystem and natural wonder.

Americans have long fought to preserve our national parks for ourselves and future generations to enjoy. The time has come once again to defend Grand Canyon National Park by keeping uranium mining activity far away from the park's boundaries.

# The Grand Canyon Is a Uniquely Valuable Natural Place

The Grand Canyon is unlike anything else on earth. Its scale—277 river miles in length, over a mile deep in places, and more than 15 miles across at its widest point—places it among the largest canyons in existence. Its geological value—three of the four eras of geologic time are represented by the canyon’s rocks—is unique.<sup>1</sup> The canyon contains remarkable biodiversity. The sharp change in elevation along its walls allows different climates and ecosystems to exist in close proximity, and the canyon and its surroundings contain three of the four types of desert that exist in North America, and five of the continent’s seven ecological zones.<sup>2</sup> The canyon is renowned for its spectacular views, and has been a tourist attraction since the late 19<sup>th</sup> century. Theodore Roosevelt, after visiting the canyon in 1903, made it a national monument in 1908; it became a national park in 1919.<sup>3</sup>

Grand Canyon National Park, which contains the canyon and much of its surrounding forest and desert, is today one of the most-visited natural attractions in the world. Nearly 4.4 million people visited Grand Canyon in 2010, making it the second-most visited national park. Only

Great Smoky Mountains National Park, which sits much nearer to major population centers on the East Coast, received more visitors.<sup>4</sup> The park draws visitors from throughout the world. In 2004, a survey found that park visitors included citizens from all 50 states. Additionally, 17 percent of park visitors had come from at least 41 different foreign countries.<sup>5</sup>

The Grand Canyon’s status as an international tourist destination makes it a powerful economic force in Arizona. It draws millions of visitors to nearby towns like Flagstaff every year, providing business for local hotels, motels, and restaurants. In 2004, tourism at Grand Canyon National Park created an estimated \$686 million of economic activity in the northern Arizona region, supporting nearly 12,000 jobs.<sup>6</sup> The broader region surrounding the canyon benefits as well; many visitors to Grand Canyon National Park make their visit part of a larger tour of attractions in Arizona and the Southwest. Other nearby national parks and attractions as far away as Las Vegas also receive a large amount of tourist traffic from visitors to the park.<sup>7</sup> Tourism is Arizona’s single largest source of out-of-state revenue, with the Grand Canyon

accounting for more than 10 percent of total visits to the state.<sup>8</sup>

Beyond the value of the canyon itself, the Colorado River, which flows through it, is one of the primary water sources for the southwestern states. 25 million people derive their drinking water from the

river, which drains large portions of seven states.<sup>9</sup> Any toxic releases or accidents that damaged the quality of the Colorado as a drinking water source would have severe consequences for the residents of California, Arizona, and Nevada.

# Mining Has Competed with Tourism for Use of the Grand Canyon

Early in its history, the Grand Canyon was explored as a mining site as well as a tourist attraction. Prospectors began to visit the area soon after the 1872 General Mining Act threw open almost all federal lands to mineral exploration and extraction. The canyon and its surroundings contain a variety of mineral deposits. The first decade of the 20<sup>th</sup> century saw a few successful efforts at developing copper and asbestos mines. Most miners, however, failed to earn much money at their chosen trade. As time went on, some early miners abandoned mining and established themselves as tour guides instead, helping transform the canyon from a site of extractive industry to a tourist attraction.<sup>10</sup>

The last mineral to inspire major mining efforts in the Grand Canyon area was uranium—a radioactive element used in nuclear weapons and as fuel for nuclear power plants. Uranium was found at the Orphan Mine—an inactive copper mine—in 1951, and that mine produced high grade ore between 1956 and 1969. Other finds followed, and several mines operated outside the park in the Arizona Strip, north of the canyon, up until the 1980s, when low prices

on the world uranium market drove them to shut down.

Mining companies are interested in the Grand Canyon area because the land around the canyon contains some of the highest-grade uranium deposits in the country. Commercially viable uranium deposits can be 1 percent uranium or less, but the Orphan Mine produced shipments composed of as much as 4.9 percent uranium, and individual samples tested as high as 80 percent uranium.<sup>16</sup> This high-grade ore is a consequence of geological formations known as breccia pipes—underground columns of loose rock glued together by a cement-like matrix. The Grand Canyon's breccia pipes formed much like sinkholes: underground erosion of limestone created a space that was filled over time by other rocks and minerals. Over time, uranium from rocks and minerals in the breccia pipes has been concentrated into the mineral uraninite. Mining of these deposits takes place through deep shaft mines.

At the same time, the Grand Canyon's uranium resources compose only an insignificant portion of the nation's overall uranium resources. The lands proposed

## The 1872 Mining Law

Hardrock mining near the Grand Canyon, as on other public lands, is governed by the General Mining Law of 1872. That law, passed with the intent of speeding the settlement of the American West by encouraging individuals to prospect for minerals on federal land, has governed the establishment of mining claims and the management of mineral deposits for more than a century.<sup>11</sup>

At its heart, the law allows anyone to establish mining rights over any suspected mineral deposit on federal land. The law also allows miners or mining companies to purchase the land surrounding a proven claim for \$2.50 to \$5.00 per acre—a process known as patenting.<sup>12</sup> Congress put a moratorium on new applications to patent mining claims in 1994, but patenting could resume at some time in the future.<sup>13</sup>

Miners or mining companies have broad discretion to carry out mining activities on land near their claims. The Bureau of Land Management needs to approve a plan of operations before mining operations can take place, which it must do unless it finds that the plan would result in “unnecessary or undue degradation of federal lands.”<sup>14</sup> Miners are required to post bonds to cover the expected cost of remediating mine sites, but those costs may be underestimated, and the Government Accountability Office has expressed concerns that the agencies regulating mines have failed to examine environmental risks and cleanup costs closely enough in the past.<sup>15</sup>

for withdrawal near the canyon contain only 12 percent of Arizona’s recoverable uranium resources.<sup>17</sup>

No new mines have opened near the canyon since the 1980s, but sites like the Orphan Mine—now a fenced-off cleanup site on the canyon’s rim—remain from the canyon’s uranium boom.<sup>18</sup> As the price of uranium has risen in the past decade, mining companies have again turned their attention toward the possibility of staking claims near the Grand Canyon.

The price of uranium greatly increased in recent years, rising from a little over \$10 per pound in 2001 to \$60 in 2008—with spot market prices even higher, up to \$136 per pound—and declining slightly since then.<sup>19</sup> In response, mining companies prepared for the resumption of mining. Several companies that explored claims and began to develop mines in the 1980s applied for permits to resume operations at those sites. Other companies have filed

new claims or applied for permits to explore potential mine sites for uranium. As of January 2003, there were only 10 claims within five miles of Grand Canyon National Park.<sup>20</sup> By June 2011, there were 3,500 claims in the area proposed for withdrawal by the Department of the Interior.<sup>21</sup> Mining companies have been moving to develop uranium mines at some of those claims; in January 2008, the Forest Service approved a request by VANE Minerals, a British mining company, to explore 39 sites near the canyon for uranium potential.<sup>22</sup>

The first mothballed mine to reopen near the canyon was the Arizona I mine, operated by the Toronto-based company Denison Mines. Denison also plans to reopen another two of its 1980s-era mines, the Pinenut and Canyon mines.<sup>23</sup>

Interior Secretary Ken Salazar imposed a two-year halt to uranium exploration and staking of new claims on one million acres around the Grand Canyon in July 2009.<sup>24</sup>

He has since extended that moratorium through the end of 2011 to allow time for further study.<sup>25</sup>

Should the moratorium on new mining sites at the canyon be lifted, uranium mining is likely to resume near the Grand Canyon on a scale much greater than that previously seen. A draft environmental impact study by the Bureau of Land Management predicted that mining companies would explore 278 sites, and actually mine at 30 sites, if the moratorium is fully lifted.<sup>26</sup> Operating this many mines near the canyon would require the construction of 22 miles of roads and power lines, and disturb approximately 1,350 acres of land—primarily north of the canyon.<sup>27</sup>

The bureau of land management has stated that ore from mines near the Grand Canyon would most likely be shipped to Utah for processing at the White Mesa uranium mill in Blanding, Utah.<sup>28</sup> It is possible, however, that under the right economic circumstances—such as high fuel costs, which raise the cost of transporting ore to distant processing sites, and the opening of a large enough number of mines near the canyon to support local processing infrastructure—a uranium mill dedicated to serving the mines in the canyon area could open nearby. If such a mill opens, the threat to the canyon area would be greatly increased by the long-term storage of toxic waste near the facility.



*The Kanab North Uranium Mine, sited along Kanab Creek and just north of the Grand Canyon, opened in the 1980s. Credit: Don Bills, USGS*

# Uranium Mining Is a Dirty, High-Risk Activity

**U**ranium mining is an inherently risky activity. Uranium, the chemicals used to extract it, and many of the substances commonly released through the process of mining it, are toxic or radioactive. Rocks and dirt removed from mines and processed to extract uranium become toxic waste; tools and equipment used in the mining and milling process eventually become radioactive; water that filters through mines or tailings becomes contaminated; even dirt from the ground surrounding uranium facilities becomes a toxic hazard when whipped up by the wind.

Some of the threats—such as those from mining—pose a direct threat to the Grand Canyon area. Other threats—such as those from milling and tailings storage—pose a greater threat to communities elsewhere in the West, but may affect the Grand Canyon as well if mining is accompanied by the development of a local processing infrastructure. The risks that uranium mining, milling, and storage pose to water supplies would threaten the Colorado River, and the downstream water supplies of millions of people

## Uranium Mining Involves Dangerous Substances

Uranium mining and processing release a number of toxic substances. These include radioactive elements, heavy metals, and other toxic substances.

### Radioactive Elements

Radioactivity comes in several forms, all of which damage cells and DNA. Electromagnetic radiation—gamma rays or x-rays—can travel through the air and harm people who spend time near a radiation source.<sup>29</sup> Alpha and beta radiation—particles emitted from atomic nuclei—cannot travel very far but do severe damage to cells if they are released from within the body, which can happen after a person drinks contaminated water or inhales contaminated dust.<sup>30</sup> Acute exposure—likely only in the case of severe radioactive accidents—results in immediate sickness, and possibly death.<sup>31</sup> Longer term exposure raises the risk of cancer and other illnesses, such as anemia and cataracts.

Uranium itself is radioactive, but a larger portion of the radioactivity in uranium ore comes from other elements,

which means that the waste from uranium mining remains radioactive even after the uranium has been removed.<sup>32</sup> As radioactive elements break down, they produce other elements—including radon, which can cause lung cancer. Radon is a radioactive gas that can escape from waste piles and travel through the air, spreading the risk of radioactive exposure over a wider area.<sup>33</sup>

Radioactivity declines over time, but some elements decay so slowly that radioactivity remains a health threat for generations.

### Heavy Metals

Rock that contains uranium may also contain toxic heavy metals. The most familiar toxic heavy metal is lead, a substance that can impair the mental and physical development of young children.<sup>34</sup> Lead can leach out of uranium mining and milling wastes and escape into the environment, as can a number of other heavy metals. Many of those metals cause problems similar to those caused by lead, in addition to other harms. Molybdenum, for instance, causes joint and respiratory problems in adults as well as threatening the development of fetuses and children.<sup>35</sup>

### Other Toxic Chemicals

In addition to radioactive elements and heavy metals, uranium mining and milling use or release a range of other toxic chemicals. Sulfuric acid—which is the most common chemical used to leach uranium out of ore at *in-situ* leaching mines, heap-leaching piles, or uranium mills—can burn skin and cause illness at high levels of exposure.<sup>36</sup> Selenium—an element that the body needs in very small doses, but which can accumulate and interfere with hormone synthesis, interfere with the immune system, cause liver damage, and even result in death in larger doses—escapes from ore alongside uranium, as does arsenic, a poison that interferes with important cell

functions, causing gastrointestinal illness, nervous system damage, cancer, and other ailments.<sup>37</sup> These substances will pose a threat near the canyon if a mill is opened there, or at whatever location is used for milling.

## Mining Damages the Environment

Producing uranium is a complicated and labor-intensive process, involving extracting and purifying ores that may contain only a tiny fraction of uranium. Large amounts of rock are excavated, soaked with chemicals, and eventually disposed of.

### Water Filtration Through Mines and Tailings

Mining uranium ore exposes the ore and the rocks that surround it to the air and weather. Though ore may contain as little as 0.1% uranium, once exposed to the air, the uranium oxidizes and becomes water-soluble, allowing it to leach into groundwater.<sup>38</sup> Other toxic substances can also leach out of tailings and mines.<sup>39</sup> Water filtering through tailings or mines can carry the toxic and radioactive contents of these waste materials into the broader environment, putting nearby water supplies at risk.

The risk that contamination could enter the Colorado River and threaten drinking water supplies has raised concern among the agencies responsible for providing water to major cities downstream. The agencies responsible for the drinking water supplies of Phoenix, Las Vegas, and Los Angeles have all registered their opposition to expanded uranium mining near the canyon, noting that a worst-case scenario involving uranium contamination could threaten the water supply of the entire drought-prone region.<sup>40</sup>

## Release of Tailings

Tailings are mine or mill waste containing processed ore, chemicals used in processing, and other contaminated liquids or debris. Tailings are stored in piles or ponds near uranium facilities. Because uranium accounts for such a small portion of the material in ore, uranium mines can generate extremely large amounts of tailings—up to 99.9 percent of the original volume of ore. Sulfuric acid, commonly used to extract uranium from tailings, also breaks molybdenum, vanadium, selenium, iron, lead and arsenic out of the ore, enabling those substances to pollute water passing through the tailings.<sup>41</sup> Even after uranium extraction, mill tailings contain 5-10 percent of the original uranium, and all of the other radioactive elements that were present in the original ore; in total, tailings are 85 percent as radioactive on average as the original ore from which they were derived.<sup>42</sup>

Accidents involving mine or mill tailings can result in environmental contamination and damage to public health. The Church Rock Mine disaster, in which a tailings pond at a New Mexico uranium mill broke open, left miles of river so contaminated with uranium that water in the area is still unsafe to drink decades later. Even smaller spills can do serious damage. When a single truck carrying ore overturned in a flash flood at the Hack Canyon mine north of the Grand Canyon, the resulting spill contaminated a watershed severely enough to necessitate long-term warnings against drinking from one of the Grand Canyon's streams.<sup>43</sup>

## Airborne Radioactive Dust

Bringing radioactive material above ground exposes it to wind as well as floods and spills. Dust from uranium mining or processing sites contains many of the hazardous materials that are present in ore, tailings, and mine debris. Uranium cleanup efforts may need dust suppression measures to prevent blown dust from becoming a health risk. At

the cleanup of the Atlas tailings pile near Moab, Utah, for instance, water spraying is required to prevent dust from escaping the site.<sup>44</sup> Uranium sites that are abandoned or temporarily shut down without being fully remediated—like the Kanab North mine site near the Grand Canyon—can become large-scale sources of radioactive dust.<sup>45</sup> If inhaled, that dust can increase the risk of lung cancer; it can also blow into streams or onto nearby ground, spreading radioactive contamination.<sup>46</sup>

## Land Disruption

Land disruption is one of the most visible and severe impacts of the mining process, although it would be less significant for mines near the Grand Canyon than it is at many other uranium sites.

Open pit mines, from which about 25 percent of the world's uranium is drawn, require the excavation of large areas of ground.<sup>47</sup> These mines produce large volumes of waste rock, which does not contain a commercially viable level of uranium but must be removed for the purpose of accessing ore. Waste rock may contain elevated levels of uranium compared to ordinary rock and is typically stored near the mine site.<sup>48</sup>

Even underground mines or *in-situ* leaching operations (in which chemicals are injected into the ground to dissolve uranium and allow it to be pumped to the surface) require a footprint—about 20 acres for underground mines of the sort that would be used near the Grand Canyon.<sup>49</sup> Radioactive dust and debris can render the area around the mine unsafe even after the mine closes, as has occurred at the Orphan Mine on the rim of the Grand Canyon.

## Ecosystem Damage

Plants and animals near uranium mines are vulnerable to several of the effects of mining—in particular, radioactive contamination and hydrological disruption.

Mines near the Grand Canyon have the

potential to introduce radionuclides into the environment and food chain and to impact the water sources local plants and animals rely on. Increased levels of radioactivity in the environment could lead to diminished vitality or death for exposed plants and animals.<sup>50</sup>

Disruption to any of the scarce springs near the canyon would impact local plants and animals by cutting off an important source of scarce water. Some water will be diverted for mine operations under any mining scenario. A larger, permanent impact might take place if mines pierce perched aquifers—an occurrence which could sharply reduce the water available to plants and animals that rely on a particular spring.<sup>51</sup>

## Each Uranium Mining and Processing Technique Poses Risks

Every uranium mining technique damages the environment and threatens public health. Each of the different kinds of facilities used to mine and process uranium carries its own risks:

- **Underground mines** extract ore from deep underground lodes and are the type of mine likely to be used near the Grand Canyon. Underground mines usually involve a deep shaft down to the level where ore is located, and a network of excavations at the depth of the ore through which uranium is removed. A mix of ore-bearing rocks and ordinary rock is excavated from these mines. Because they are more expensive to build and operate, deep underground mines are likely to be used only for relatively high-grade ore deposits.<sup>52</sup>
- **Open-pit mines** are mines where uranium-bearing ore is extracted from a large pit, in a fashion similar to quarrying stone. These mines have the largest surface footprint of any uranium operation, both from the mine itself and from the land required to store the overburden and ore removed.<sup>53</sup>
- **In-situ leaching mines** are low-cost mines that extract uranium from underground deposits located in aquifers trapped within impermeable rock. Leaching fluid is circulated through a uranium deposit through wells drilled down into the deposit, extracting uranium from the rock. Uranium is recovered by pumping the fluid back to the surface. If fluid escapes from a well or from the underground deposit, groundwater can be contaminated.<sup>54</sup>
- **Heap leaching** is a method for extracting uranium from low-grade ore by running sulfuric acid or another chemical through piles of ore at a mine site to extract the uranium. These heaps become large tailings piles once leaching ends; they contain many of the toxic substances often found in tailings, and can contaminate the land and water under them.<sup>55</sup>
- **Uranium mills** are used to process higher-grade ores by grinding up the rock and using sulfuric acid or another chemical to extract uranium. Mills produce large amounts of tailings—and, in fact, often centralize the tailings from multiple mines at a single location, leading to potentially very large tailings piles. Mill equipment also requires special handling when the facilities are decommissioned; the equipment is radioactive and poses health risks without proper disposal.<sup>56</sup>

# Uranium Mining Has a Track Record of Environmental Contamination

In four decades of heavy mining—from the 1950s through the 1980s—the U.S. uranium industry left a toxic trail of contaminated sites across the American West. Contaminated sites include mines, mills, tailings piles, and the sites of accidental spills. Some of the first sites used by the uranium industry are still contaminated today; the Atlas Uranium Mill near Moab, built to process ore from one of the country’s first major uranium strikes, left behind a tailings pile that still threatens the Colorado River. Some of the last mines to open are also still a threat; the Kanab North Mine, an underground mine near the Grand Canyon, has been placed on “standby”—indefinite closure, with the possibility of returning to active use at a later date—without cleanup.

The uranium industry came into existence to produce bomb-making material to meet the needs of the U.S. military’s nuclear program. In the 1970s, as the military stepped down its uranium purchasing, uranium mines and mills found a new market as fuel providers to the civilian nuclear power industry. By the 1980s, though, worldwide demand for newly extracted uranium had fallen, as reprocessed reactor

fuel and repurposed uranium from decommissioned nuclear weapons supplied a large portion of the civilian nuclear industry’s needs. Mine and mill closures swept through the U.S. uranium industry.

Every uranium site is hazardous while in use (as discussed in the previous section), and needs to be cleaned up afterward. Uranium itself, the chemicals used to extract it, and many of the byproducts that emerge from ore alongside it are toxic. These contaminants can do lasting damage to uranium sites and the land and water around them. Sick families, poisoned streams, and lasting threats to the drinking water of millions have been among the results of uranium mining in the past. The case studies below describe a range of sites and incidents—in multiple states, at multiple types of uranium facilities, across multiple decades—that illustrate the risks uranium mining has posed in the past, and will continue to pose in the future.

Several of these sites closely resemble potential new mines near the Grand Canyon. The incidents described in Arizona and New Mexico both affected the Grand Canyon area, and those in Arizona actually took place at mines near the canyon.



*Abandoned equipment and structures for the Orphan Mine on the rim of the Grand Canyon in 2007, decades after the mine closed and shortly before the National Park Service removed them from the site. Photo Credit: Alan Levine, used under Creative Commons Attribution License.*

The other case studies below illustrate the risks that uranium extracted from any mine poses to the areas where ore is processed and waste is stored, and the overall risk that the uranium industry poses to human health and the environment.

## Arizona: Fouled Streams, Damaged Aquifers, and Toxic Dirt Piles

If uranium mining companies are allowed to develop new mines near the Grand Canyon, it won't be the first time that the canyon has hosted uranium mining activities. Nor will the impacts of any new mining be the first damage uranium has done to the canyon; the park already bears the scars of a previous round of extraction.

During the mid-century uranium boom, a handful of uranium mines operated near the Grand Canyon—in one case, right up to the canyon's edge. These mines have left an indelible mark on the canyon and its surroundings, from fouled streams and damaged aquifers to lingering piles of radioactive debris.

Every year, 1.5 million park visitors head west from Grand Canyon Village toward the historic El Tovar Hotel and the popular Hermit Overlook; on the way, they detour away from the canyon's rim to avoid the Orphan Mine, an abandoned uranium mine surrounded by fences and warning signs to keep park visitors away.

The Orphan Mine—a 1,500-foot deep underground mine that produced high-grade uranium ore from 1956 to 1969—began its life as an unsuccessful copper mine, then sat idle for decades as the mine's owners put their land to use for the more profitable tourism business. The

discovery of uranium in 1951 changed their profit incentive, and the mine resumed activity shortly thereafter. The mine owners ultimately secured permission to mine uranium within the boundaries of Grand Canyon National Park. (The federal government was originally reluctant to give that permission, but relented after the mine owners threatened to build an 18-story hotel descending down the rim of the canyon.<sup>57</sup>)

Today, the mine site is controlled by the National Park Service, and access is restricted because soil radiation levels are 450 times above normal.<sup>58</sup> The National Park Service recently removed the mine structures from the rim; total cleanup of the contamination on the surface will cost \$15 million, which the Park Service hopes to eventually recoup from the defense contractors responsible for the mine.<sup>59</sup>

Two creeks near the mine, meanwhile, contain high quantities of uranium in their water. Horn Creek, flowing from a spring near the mine, crosses a popular trail through the canyon, but hikers are warned not to drink the water; its uranium content is too high for safe consumption. Nearby Salt Creek bears a similar warning.<sup>60</sup>

The Orphan Mine is an underground uranium mine, a series of tunnels underground from which miners pulled ore when the mine was active. Mines of this sort are less disruptive of the land's surface than open pit mining, but in a landscape like the Grand Canyon they bear risks of their own. By disrupting and opening up the rock formations in which uranium is sealed underground, mines can open pathways for water from mine tunnels to enter aquifers, including the limestone from which the Grand Canyon's springs emerge.<sup>61</sup> If new underground mines open near the canyon's rim, more springs could be contaminated as uranium finds its way down into aqui-

fers. Even mines that don't introduce contamination can harm local water supplies by piercing the impermeable rocks that support perched aquifers—isolated pools of groundwater elevated above the overall water table, which are the source of many of the park's springs. Exploratory drilling for the Canyon Mine—a potential mine site that was developed but never mined in the 1980s, now slated to reopen under the control of Denison—pierced such an aquifer, draining an estimated 1.3 million gallons of water per year from area springs.<sup>62</sup>

Another old Grand Canyon mine demonstrates a different, more direct, path to stream contamination. The Hack Canyon Mine, on the Grand Canyon's less-traveled north rim, is a deep shaft mine like the Orphan Mine, which produced 9.5 million tons of uranium over the course of its lifetime.<sup>63</sup> The mine made its lasting radiological mark on the area in 1984, when a summer flash flood swept 4 tons of high grade uranium ore from the mine site into nearby Kanab Creek; the National Park Service advises visitors not to drink or bathe in the creek because of its radioactivity levels.<sup>64</sup>

Hack Canyon isn't the only mine to introduce uranium into Kanab Creek, just the one that did so in the most spectacular fashion. Ongoing contamination of the area comes from several shuttered mines near the creek. Federal law requires mining companies to reclaim mines when they close, but mines that are placed on "stand-by"—indefinite temporary closure, often triggered by a fall in mineral prices—can remain unreclaimed for decades. At Kanab North Mine, for instance, a 350-foot long tailings pile remained behind when mining operations stopped in the 1980s; it remains uncovered, allowing the wind to blow uranium-laden dust into the Kanab Creek watershed.<sup>65</sup>

## New Mexico: A Giant Spill and an Ongoing Cleanup

Beginning in the 1950s, uranium mines sprang up in the New Mexico's Grants Mineral Belt, which spans Cibola, McKinley, Sandoval, and Bernalillo counties, as well as Navajo Tribal lands.<sup>66</sup> When uranium prices fell, the industry left, and left extensive contamination behind; the EPA estimates that 130 different mine sites in New Mexico still need to be cleaned up.<sup>67</sup>

A uranium mill that served New Mexico's mines was the site of the worst uranium accident in the United States. The Church Rock Mill, owned by the United Nuclear Corporation, operated from 1977 to 1982, processing ore from mines in the area.<sup>68</sup> In 1979, an earthen dam burst at the mill's tailings pond. Behind that dam were 94 million gallons of acidic water, laden with uranium tailings. The radioactive flood that resulted spilled down the north fork of the Rio Puerco and into the Little Colorado River; within days, water sources as far as 50 miles downstream in Arizona had been polluted.<sup>69</sup> Though less well publicized, the Church Rock Disaster was actually larger, in terms of the volume of radioactive material released, than the Three Mile Island nuclear power plant accident.<sup>70</sup>

Today, the mill and the nearby Northeast Church Rock Mine remain the worst of the 20 abandoned uranium sites in the Church Rock area of New Mexico. Problems extend beyond the spill; while it operated, the mine piled up waste in heaps outside the mine, and pumped radioactive water out of mineshafts to dry up in pools on the ground above. The ongoing contamination stemming from those waste heaps and pools led the U.S. Environmental Protection Agency to declare the mine a Superfund site, starting a cleanup process that still continues today.



*Aerial view of the cleanup site at the former Church Rock Uranium Mill. The former location of the tailings pond is visible in the bottom right half of the photograph. Credit: U.S. EPA*

When the United Nuclear Corporation (UNC) closed the Northeast Church Rock Mine, it failed to clean all the radioactive sediments out of the pools it had used to treat radioactive mine water. Now, those pools fill with rainwater instead, creating dangerous and unhealthy surface water. Water from the final treatment pool poured out into an arroyo that runs between houses in the community of Church Rock; that arroyo, too, is contaminated.<sup>71</sup>

The mine waste piles, meanwhile, contain low-grade uranium, other radioactive elements, and heavy metals. Those piles—now partly covered by plants—pose a risk to people who walk through the area. Dirt blows off the piles in the wind and runs off in rainwater to spread contamination to the surrounding area.<sup>72</sup>

People who inhale contaminated dust particles or utilize contaminated rainwater or runoff that has pooled in ponds around the site face elevated health risks from Radium-226, which is found in high concentrations on the 125-acre site. Among the health risks are “anemia, cataracts, fractured teeth, cancer (especially bone cancer), and death,” according to the EPA.<sup>73</sup> Additionally, many homes and storage structures have been constructed

from contaminated materials from nearby mines. “Building material sources may include rocks from the mine and aggregate from mine spoils which may have been used in concrete mixing. Structures may also be contaminated by the presence of radiological materials in outdoor soils and dust that may have been brought into the homes on shoes and clothing,” according to the EPA.<sup>74</sup> The EPA demolished at least 35 structures between 2008 and the end of 2010.<sup>75</sup>

The Northeast Church Rock Mine continues to poison the land, air and water around it decades after being shut down. Even with cleanup efforts underway, the people of the community near the mine are surrounded by sources of dangerous contamination every day, which pose severe health risks not only for them, but also for future generations.

## The Atlas Mill at Moab: 16 Million Tons of Radioactive Rubble

Today, the town of Moab, Utah is most famous for outdoor recreation. Mountain bikers, hikers, and all-terrain vehicle riders travel from all over the country to visit the area’s wide-open landscapes and striking red rocks. Moab got its start, though, as one of the nation’s biggest hubs of uranium mining and processing.

Uranium was discovered near Moab in 1953, and a boom started immediately. Moab’s population shot from 1,200 to 6,000 in less than a year, and Charlie Steen, the impoverished prospector who made the first uranium strike, suddenly found himself rich enough to build a mill for his ore.<sup>76</sup>



*The Atlas Mill tailings pile near Moab. The Colorado River is visible in the right of the photograph. The Department of Energy expects that fully removing the pile will take until 2025 at current funding levels. Photo Credit: Department of Energy.*

That mill, completed in 1956 and purchased in 1962 by the Atlas Uranium Corporation, operated from 1956 to 1982. Milling uranium involves crushing ore and running sulfuric acid or another chemical through it to extract the uranium. It produces large volumes of waste; since uranium composes only a tiny fraction of the material in ore, 99 percent or more of the rock extracted from a mine can wind up in a tailings pile. That waste retains 85 percent of the radioactivity of the original underground deposit.<sup>77</sup>

In 1982, the collapsing price of uranium rendered the Atlas Mill uneconomical, and it closed. Left behind was a 130-acre, 16 million ton pile of toxic and radioactive tailings located 750 feet from the edge of the Colorado River, a source of drinking water for 25 million downstream residents.<sup>78</sup> Among the cities that rely on the Colorado for drinking water are San Diego, Las Vegas, Phoenix, and Los Angeles.<sup>79</sup>

That tailings pile remained untouched for almost three decades, from 1982 to 2009, and most of it is still in place today. Over that period, it has steadily leaked uranium and other toxics into the aquifer underneath it, the land between the pile and the river, and the river itself. By the late 1990s, uranium concentrations beneath the pile were 31 times the safe limit, lead concentrations 20 times their limit, and ammonia concentrations 6 times their limit—to name just a few of the 20 toxic substances found at unsafe levels in the vicinity of the pile.<sup>80</sup> Every day, as much as 28,000 gallons of contaminated water from the pile makes its way into the Colorado River.<sup>81</sup> In a flood, or if the course of the river shifted, large amounts of toxic waste could be swept into the river.<sup>82</sup>

Atlas Uranium, under pressure to address the risk posed by the tailings, proposed to “cap” the pile with layer of rock and clay; in the midst of a regulatory battle over whether that measure would be sufficient, the company went bankrupt, leaving

the government with full responsibility for the tailings pile.<sup>83</sup> A multi-year legal and legislative struggle ensued, as local residents and downstream water users fought to get the tailings relocated to a safer site away from the river.

After the federal government agreed to remove the tailings, cleanup began in 2009, but the size of the pile ensures that the risk will remain for a while. A cleanup effort expanded by funds from the American Reinvestment and Recovery Act (ARRA) removed 4 million tons of waste between 2009 and 2011, but, with the expiration of the ARRA funds in 2011, the Department of Energy expects to need another 14 years—until 2025—to complete the project.<sup>84</sup>

## Colorado: Poisoned Well Water and Sick Residents

For decades, residents of Lincoln Park, a small community near the Cotter Corporation Uranium Mill outside of Cañon City, Colorado, got their drinking water from wells near the mill. Today, they rely instead on treated water from Cañon City’s water system, since their groundwater is no longer safe to drink.

From 1958 to 1979, the Cañon City uranium mill stored its waste in unlined pools on the mill’s grounds.<sup>85</sup> The result was a toxic plume in groundwater surrounding the plant—a pool of contamination that required the EPA to declare the mill and its surroundings a Superfund toxic waste site and remove tons of contaminated soil from the area.

When uranium processing takes place near residences, the wastes it produces can pose a serious threat to human health—even years after the processing is complete. Stored waste from the decades

of uranium processing at the Cotter Mill was the source of contamination that led to the poisoning of a community's water supply.

Uranium was not the only toxic substance to which residents of Lincoln Park were exposed. Uranium milling both uses and releases a wider variety of toxic chemicals—from the sulfuric acid commonly used for extracting the uranium to the molybdenum and other heavy metals that leach out of the ore along with uranium. Among the chemicals found in the soil near the Cotter Mill were uranium, arsenic, molybdenum, lead, cobalt, nickel, selenium, zinc, copper and cadmium.<sup>86</sup>

Federal investigators found that heavy metal contamination of well water accounted for the worst of the health threats from the Cotter Mill, putting residents at particular risk of joint and respiratory problems.<sup>87</sup> Lincoln Park's residents switched from well water to municipal water to avoid these risks, but only after decades during which they unknowingly consumed contaminated well water. Other health risks came from the soil—govern-

ment scientists warned that properties near the mill might be too contaminated to develop safely as homes—and contamination of local vegetable gardens with arsenic and other poisons.<sup>88</sup>

The impacts on the community were severe. Residents of the area suffered from birth defects, arthritis, and cancer, among other illnesses; medical experts have testified that contamination from the mill contributed to these health problems.<sup>89</sup> Residents have fought through several rounds of litigation with the Cotter Corporation, winning various settlements and awards worth millions of dollars, but facing persistent appeals and denial of responsibility from the mill company.<sup>90</sup> Long term plans for cleaning up the site after the mill closes remain uncertain; Cotter has set aside \$20 million for the eventual decommissioning of the mill, but that sum is just under half of the total estimated cost of the cleanup.<sup>91</sup> In Colorado alone, taxpayers have already spent more than \$1 billion dollars cleaning up past uranium milling operations according to U.S. Department of Energy and U.S. EPA documents.<sup>92</sup>

# Policy Recommendations

The Grand Canyon is one of the most impressive, unique, and treasured wild places in the United States. Uranium mining is one of the dirtiest and riskiest industries. The two do not belong together.

Since 2009, a moratorium on mining has protected the area around the Grand Canyon from the development of new mining claims. Because of low uranium prices, no new claims were developed for two decades before 2009. Now, however, with uranium prices high, an end to the moratorium on uranium mining near the canyon could lead to a rush of new mining activity on the lands around Grand Canyon National Park. To properly protect the park for future generations, we need to ensure that no new uranium mining takes place there. In the longer term, other places deserve that same protection, including other national parks and important waterways. In order to achieve this, policymakers should:

- **Place a 20 year moratorium on new claims and exploration in a million-acre area surrounding the Grand Canyon.** This action, the strongest allowed by the Federal Land Policy

and Management Act and identified by Interior Secretary Salazar as the Interior Department's preferred option, would protect the Grand Canyon from the worst impacts of expanded uranium mining. Extending the moratorium to the full million acre package of land under consideration is the best way to keep the risks inherent in uranium mining and processing at a safe remove from the Grand Canyon.

- **Reform mining laws to allow regulators to deny permission to mine where significant natural places or human health are at risk.** Current mining law is too lax in granting mining companies the right to stake and develop claims with a very limited permitting process. Most federal land is considered open for mining by default, and regulators lack sufficient power to weigh the costs and benefits of mining against other possible uses of the land. Mining should be placed on an even footing with recreation and other land uses by allowing regulators to make a balanced evaluation of the best use of federal lands.

- **Require uranium mining companies to clean up contamination.** Uranium companies should be required to post enough money to cover the full cost of reclamation at mine and mill sites before beginning operations. Costs should cover all foreseeable reclamation activities, as

well as insurance against accidents that would significantly raise cleanup costs. Additionally, companies should not be allowed to place mines on “standby” without cleaning them up sufficiently to prevent the spread of contamination.

# Notes

- 1 National Park Service, *Grand Canyon National Park: Nature and Science*, 15 November 2010.
- 2 Ibid.
- 3 Michael F. Anderson, *Polishing the Canyon: An Administrative History of Grand Canyon National Park*. Grand Canyon, AZ: Grand Canyon Association, 2000.
- 4 National Park Service, *Ranking Report for Recreation Visits in 2010*, downloaded from [www.nature.nps.gov/stats/viewReport.cfm](http://www.nature.nps.gov/stats/viewReport.cfm) on 16 May 2011.
- 5 Arizona Hospitality Research and Resource Center, Northern Arizona University, *Grand Canyon National Park & Northern Arizona Tourism Study*, April 2005.
- 6 Ibid.
- 7 Ibid.
- 8 Arizona Office of Tourism, *Arizona Tourism Industry Maintains Vital Impact to State* (press release), 9 July 2009. “Over 10 percent” based on 2008 tourism figures.
- 9 “Moab Uranium Tailings Pile Starts Moving at Last,” *Environment News Service*, 6 May 2009.
- 10 Michael Anderson, Arizona State University and Grand Canyon Association, *Nature, Culture and History at the Grand Canyon*, downloaded from [grandcanyonhistory.clas.asu.edu/history\\_loggingminingranching\\_mining.html](http://grandcanyonhistory.clas.asu.edu/history_loggingminingranching_mining.html), 23 May 2011.
- 11 Robert McClure and Andrew Schneider, “The General Mining Law of 1872 Has Left a Legacy of Riches and Ruin,” *Seattle Post-Intelligencer*, 10 June 2001.
- 12 43 CFR 3860
- 13 U.S. Department of the Interior, Bureau of Land Management California, *Mineral Patents*, 22 August 2007, downloaded from [www.blm.gov/ca/st/en/prog/minerals/patents.html](http://www.blm.gov/ca/st/en/prog/minerals/patents.html) on 21 June 2010.
- 14 43 CFR 3809.411
- 15 Jane Perlez and Kirk Johnson, “Beyond Gold’s Glitter: Torn Lands and

- Pointed Questions,” *New York Times*, 14 June, 2010.
- 16 Grand Canyon Treks, *The Orphan Mine!*, downloaded from [www.grandcanyontreks.org/orphan.htm](http://www.grandcanyontreks.org/orphan.htm), 23 May 2011.
- 17 U.S. Geological Survey, *Breccia Pipe Uranium Mining in Northern Arizona—Estimate of Resources and Assessment of Historical Effects*, January 2011.
- 18 Tara Alatorre, “Federal Plan to Close Land Won’t End Uranium Mining Near Grand Canyon,” *Cronkite News*, 9 May 2010.
- 19 U.S. Department of Energy, Energy Information Administration, *Uranium Marketing Annual Report*, 18 August 2010. Spot prices: Cameco Corp, *Uranium Prices*, downloaded from [www.cameco.com/investors/uranium\\_prices\\_and\\_spot\\_price/](http://www.cameco.com/investors/uranium_prices_and_spot_price/) on 6 June 2011.
- 20 Pew Environment Group, *Ten Treasures at Stake*, 2011, available at [www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/10%20Treasures.pdf](http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/10%20Treasures.pdf)
- 21 U.S. Department of the Interior, *Fact Sheet: Proposed Mineral Withdrawal Near Grand Canyon National Park*, 20 June 2011.
- 22 Felicity Barringer, “Uranium Exploration Near Grand Canyon,” *New York Times*, 7 February 2008.
- 23 See note 18.
- 24 Associated Press, *Critics Blast Report on G. Canyon Uranium Mining*, 15 May 2011.
- 25 John Broder, “Uranium Mine Moratorium Extended at Grand Canyon,” *New York Times*, 20 June 2011.
- 26 Bureau of Land Management, *Northern Arizona Proposed Withdrawal Draft Environmental Impact Statement*, 2011.
- 27 Ibid.
- 28 Ibid.
- 29 Radiation Emergency Assistance Center/Training Center, *Characteristics of Gamma Radiation and X-Rays*, downloaded from [orise.orau.gov/reacts/guide/gamma.htm](http://orise.orau.gov/reacts/guide/gamma.htm) on 21 June 2011.
- 30 Health Physics Society, *What Types of Radiation Are There?*, downloaded from [www.hps.org/publicinformation/ate/faqs/radiationtypes.html](http://www.hps.org/publicinformation/ate/faqs/radiationtypes.html) on 21 June 2011.
- 31 Radiation Emergency Assistance Center/Training Center, *Types of Radiation Exposure*, downloaded from [orise.orau.gov/reacts/guide/injury.htm](http://orise.orau.gov/reacts/guide/injury.htm) on 21 June 2011.
- 32 William Sweet, “Unresolved: The Front End of Nuclear Waste Disposal,” *Bulletin of the Atomic Scientists*, May 1979.
- 33 U.S. Environmental Protection Agency, *A Citizen’s Guide to Radon*, downloaded from [www.epa.gov/radon/pubs/citguide.html](http://www.epa.gov/radon/pubs/citguide.html) on 21 June 2011.
- 34 U.S. Environmental Protection Agency, *Lead in Paint, Dust, and Soil*, downloaded from [epa.gov/lead/pubs/leadinfo.htm](http://epa.gov/lead/pubs/leadinfo.htm) on 22 May 2011.
- 35 States News Service, *ATSDR Releases Report on Lincoln Park Cotter Mill Uranium Site*, 9 September 2010 and World Health Organization, *Molybdenum*

*in Drinking Water: Background Document for Development of WHO Guidelines for Drinking Water Quality*, 2003.

36 Jacob L. Heller, MD, MHA, "Sulfuric Acid Poisoning," in *Medline Plus Encyclopedia*, 30 September 2009.

37 Selenium: M. Vinceti et al, "Adverse Health Effects of Selenium in Humans" *Review of Environmental Health*, July-September 2001, 233-51. Arsenic: RN Raitnake, "Acute and Chronic Arsenic Toxicity," *Postgraduate Medical Journal*, July 2003, 391-396.

38 0.1%: International Atomic Energy Agency, *Advances in Uranium Ore Processing and Recovery From Non-Conventional Resources*, 1985. Leach: See note 18.

39 Robert F. Kaufman, Gregory G. Eadie and Charles R. Russell, U.S. EPA, *Summary of Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico*, August 1975.

40 Environmental Working Group, *Colorado River Agencies Urge Caution on Uranium Mining Near Grand Canyon* (press release), 17 May 2010.

41 U.S. EPA, "Uranium" in *Identification and Description of Mineral Processing Sectors and Waste Streams*, downloaded from [www.epa.gov/osw/nonhaz/industrial/special/mining/minedock/id/id4-ura.pdf](http://www.epa.gov/osw/nonhaz/industrial/special/mining/minedock/id/id4-ura.pdf) on 7 July 2010.

42 See note 32.

43 Jim Mimiaga, "Study: Mining Near Grand Canyon Could Threaten Water," *Four Corners Free Press*, May 2010.

44 Moab UMTRA Project Information, *Frequently Asked Questions*, downloaded

from [www.moabtailings.org/faq.htm](http://www.moabtailings.org/faq.htm), 23 May 2011.

45 See note 18.

46 U.S. National Research Council, *Scientific Basis for Risk Assessment and Management of Uranium Mill Tailings*. Washington: National Academy Press, 1986, p. 4.

47 25 percent: World Nuclear Association, *World Uranium Mining*, April 2011.

48 See note 41.

49 Eugene V. Spiering, Quatterra Resources Inc., *Exploration and Discovery of Blind Breccia Pipes: The Potential Significance to the Development of the Arizona Strip District, Northern Arizona* (presentation delivered at Society of Mining Engineers 2010 Annual Meeting), 1 March 2009.

50 See note 26.

51 Ibid.

52 International Atomic Energy Agency, *Methods of Exploitation of Different Types of Uranium Deposits*, September 2000.

53 Ibid.

54 U.S. EPA, "Appendix III: Occupational and Public Risks Associated with In-Situ Leaching" in *Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining Volume 2: Investigation of Potential Health, Geographic, and Environmental Issues of Abandoned Uranium Mines*, April 2008.

55 See note 41.

- 56 Department of Energy, Energy Information Administration, *Decommissioning of U.S. Uranium Production Facilities*, February 1995.
- 57 Dana Bennett, Arizona State University Nature, Culture and History at the Grand Canyon Project, *Orphan Mine*, downloaded from [grandcanyonhistory.clas.asu.edu/history\\_loggingminingranching\\_orphanmine.html](http://grandcanyonhistory.clas.asu.edu/history_loggingminingranching_orphanmine.html) on 13 May 2011.
- 58 Mark Clayton, “Do Uranium Mines Belong Near Grand Canyon?” *Christian Science Monitor*, 19 August 2008.
- 59 John Dougherty, “McCain Turns Back on Grand Canyon,” *Washington Independent*, 22 July 2008.
- 60 See note 58.
- 61 Ibid.
- 62 See note 18.
- 63 See note 49.
- 64 See note 43.
- 65 See note 18.
- 66 “Uranium News – Legacy Issues: Agencies Join to Seek Solutions,” *Cibola Beacon*, 22 October 2009.
- 67 Ibid.
- 68 U.S. Nuclear Regulatory Commission, *UNC – Church Rock Mill Uranium Recovery Facility*, downloaded from [www.nrc.gov/info-finder/decommissioning/uranium/is-united-nuclear-corporation-unc.pdf](http://www.nrc.gov/info-finder/decommissioning/uranium/is-united-nuclear-corporation-unc.pdf) on 5 May 2011.
- 69 See note 66.
- 70 Doug Brugge et al., “The Sequoyah Corporation Fuels Release and the Church Rock Spill: Unpublicized Nuclear Releases in American Indian Communities,” *American Journal of Public Health* 97(9): 1595–1600, September 2007.
- 71 U.S. Environmental Protection Agency, *Region 9 Superfund: Northeast Church Rock Mine*, downloaded from [yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dec8ba3252368428825742600743733/9beb6aeaf2fa058a88257353002bf7d6](http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dec8ba3252368428825742600743733/9beb6aeaf2fa058a88257353002bf7d6) on 5 May 2011.
- 72 Ibid.
- 73 Ibid.
- 74 U.S. Environmental Protection Agency, *Addressing Uranium Contamination in the Navajo Nation: Contaminated Structures*, downloaded from [www.epa.gov/region9/superfund/navajo-nation/contaminated-structures.html](http://www.epa.gov/region9/superfund/navajo-nation/contaminated-structures.html), 5 May 2011.
- 75 Ibid.
- 76 David Hasemyer, “At the Edge of the Colorado River – San Diego County’s Main Source of Water – Sits a Massive Reminder of What the Atomic Age Left Behind,” *San Diego Union-Tribune*, 23 August 1998.
- 77 See note 32.
- 78 See note 9.
- 79 Environmental Working Group, *Mining Surge Near Colorado River Threatens Drinking Water for 25 Million* (press release), 5 May 2008.
- 80 See note 76.
- 81 David Hasemyer, “Radioactive

Waste Pile Under Attack: Pressure Mounts to Move Threat to Drinking Water,” *San Diego Union-Tribune*, 27 December 1998.

82 Matt Jenkins, “Colorado River Kisses a Toxic Mess Good Bye,” *High Country News*, 2 May 2005.

83 Lisa Church, “Interior Secretary, Utah Delegation Join in Turning Up Pressure to Move Moab Tailings Pile; Pressure Is On To Move Tailings Pile Near Moab,” *Salt Lake Tribune*, 24 November 1998.

84 Judy Fahys, “Tailings Cleanup to Slow as Stimulus Money Dries Up,” *Salt Lake Tribune*, 10 May 2011.

85 Colleen Long, “EPA Says Soil Cleanup at Cañon City Superfund Site is Finished,” *Associated Press*, 4 January 2002.

86 Tom McAvoy, “Victims of Radiation Poisoning from Cañon City, Colo., Awarded \$16 Million,” *Pueblo Chieftain*, 2 July 2001.

87 States News Service, *ATSDR Releases Report on Lincoln Park Cotter Mill Uranium Site*, 9 September 2010.

88 Ibid.

89 Tom Ragan, “Because of Contamination, Mill Finds Itself at the Center of a Struggle,” *The Gazette* (Colorado Springs, CO), 27 August 2001.

90 “Primary Insurers Have Duty To Defend Corporation In Tort Actions Concerning Hazardous Materials, But Excess Insurers Have No Such Duty; COTTER CORPORATION v. AMERICAN EMPIRE SURPLUS LINES INSURANCE COMPANY, No. 02SC707 (Colorado Supreme Court May 17, 2004),” *Digest of Environmental Law*, August 2004.

91 “Group Sues Cotter Corp. Over Uranium Mill Cleanup,” *Associated Press*, 22 September 2010.

92 Environment Colorado, *Cleaning-Up a Toxic Legacy; Elected Officials, Business, and Advocates Gather in Canon City to Announce New Legislation to Strengthen Clean-Up at Uranium Processing Facilities* (press release), 26 January 2010.

