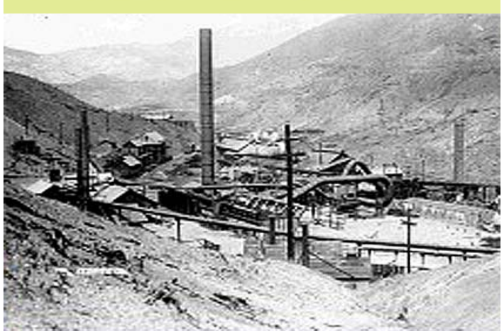
Abandoned Mine Lands Case Study

Iron Mountain Mine

Success Through Planning, Partnerships, and Perseverance

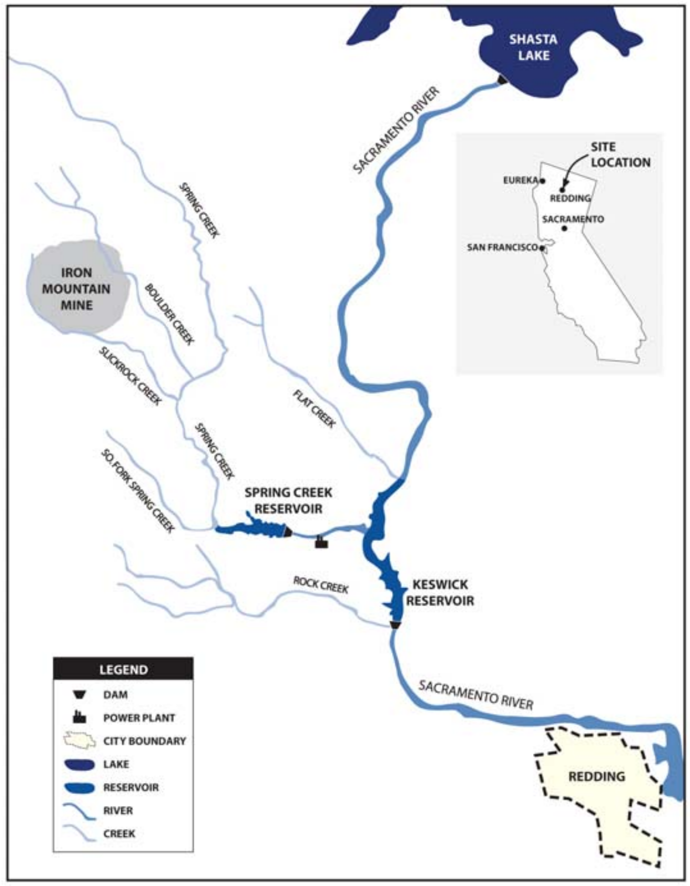
- Mining at Iron Mountain began in the mid 1890s and ended in 1963.
- The uncontrolled acid mine drainage from Iron Mountain Mine was the largest source of surface water pollution in the U.S. and accounted for roughly one-fourth of the entire national discharge of copper and zinc to surface waters from industrial and municipal sources.
- EPA's cleanup and pollution control measures have reduced the discharge of acidity, copper, cadmium, and zinc by 95 percent.
- A financial settlement with the responsible parties provides for the operation and maintenance of the on-site treatment facilities far into the future.



Early in its history, Iron Mountain Mine was famous for being the most productive copper mine in California and one of the largest in the world. In recent years, the legacy of mining at Iron Mountain turned its fame to infamy, as the site became known as the largest source of surface water pollution in the United States and the source of the world's most corrosive water. Even so, 40 years after the cessation of mining activities, scientists seeking to understand how to control the risks posed by the site made a valuable discovery of a different kind at Iron Mountain: a new species of microbe that thrives in the extreme conditions deep within the mountain. While pollution from the site has not posed any great risk to the approximately 100,000 people living in the nearby City of Redding, the same can not be said for the salmon, trout, and other aquatic organisms that have struggled for survival downstream of Iron Mountain. More than 20 years of work by EPA, other Federal and California State agencies, and potentially responsible parties (PRPs)—much of it underwritten by Superfund—is finally paying off in a big way. Remediation and pollution control activities now neutralize almost all the acid mine drainage and control 95 percent of the copper, cadmium, and zinc that used to flow out of Iron Mountain into nearby streams and then into the Sacramento River. Furthermore, EPA and the State of California secured funding from one of the site's previous owners in one of the largest settlements with a single private party in Superfund history. The settlement terms should enable continuous operation and maintenance of the treatment facilities for the foreseeable future.

March 07, 2006

SITE HISTORY



Iron Mountain is located in Shasta County, California, in the southeastern foothills of the Klamath Mountains, approximately 14 km (8.7 mi) northwest of the City of Redding. The mineral deposits within Iron Mountain define the southernmost end of the West Shasta mining district.

The Superfund site known as Iron Mountain Mine (IMM) encompasses approximately 1,800 hectares (4,400 acres) and comprises many distinct mines, the site of the former flotation mill at Minnesota Flats, the Matheson Rail Loading Station site, and the Spring Creek Arm of Keswick Reservoir. Between the mid 1890s, when the Old Mine was first excavated to extract copper ore, and 1963, when mining activities ceased, nearly ten separate mines were excavated at Iron Mountain, including Old Mine, No. 8 Mine, Richmond Mine, Hornet Mine, Confidence-Complex Mine, Mattie Mine, and the open pit mine at Brick Flat near the mountain's summit.

Geologists refer to formations like Iron Mountain as massive sulfide deposits. The deposits in the West Shasta mining district formed 350 to 400 million years ago in an island-arc setting in a marine environment as a result of geothermal hot springs on the sea floor expelling sulfur-rich hydrothermal fluids.

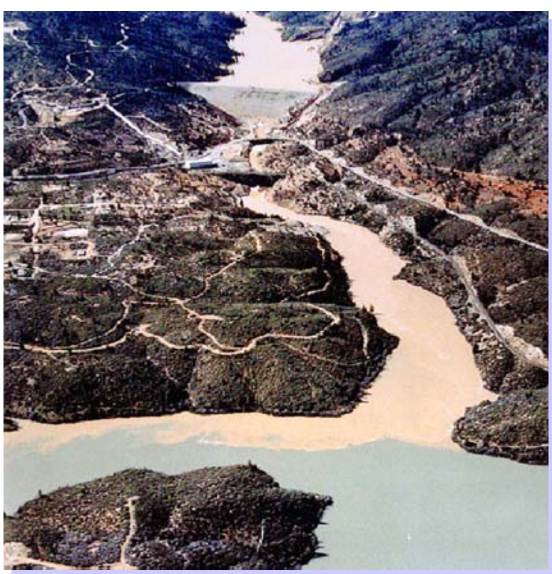


Photo 1: Before cleanup began at the site, IMM discharged, on average, five tons of iron, 650 pounds of copper, and 1,800 pounds of zinc per day into Spring Creek and Keswick Reservoir.

In the 1860s, surveyor William Magee and settler Charles Camden noticed the striking red color of the rock outcrop on the south face of Iron Mountain and deduced the presence of "an immense iron deposit." In 1879, James Sallee discovered that the red rock—known as *gossan*: rust-colored, oxidized iron ore—contained silver as well as iron, and he, Magee, and Camden began mining the gossan and extracting the silver. In the mid 1890s, the sulfide deposits within the mountain were discovered, and copper mining commenced. In subsequent years, Iron Mountain was also mined for gold, iron, zinc, and pyrite (iron sulfide); pyrite, a source of sulfur, was used to manufacture munitions and fertilizers and in petroleum refining. California State records indicate that between 1888 and 1965, Iron Mountain yielded 313 million pounds of copper, 265,314 ounces of gold, 24 million ounces of silver, 2.6 million pounds of sulfur, and sizeable quantities of zinc and iron. At one time, IMM was the largest copper producer in California, the sixth largest in the U.S., and the tenth largest in the world.

REGULATORY HISTORY

Photo 2: Entrance to the refurbished Richmond adit, showing the ventilation exhaust system.

In 1976, the State of California adopted regulations making owners of inactive mine sites responsible for meeting Federal Clean Water Act standards for pollution. Between 1976 and 1982, the State fined IMM owners for unacceptable releases of metals. In February 1982, the State of California initiated legal action against the site owner, Iron Mountain Mines, Inc. (which purchased the site from Stauffer Chemical Company in 1976). The State's legal action resulted in a default judgment against the company and fines totaling $16.8 million. In June and July 1982, Iron Mountain Mines, Inc. filed motions to vacate the default judgments, which the Shasta County Superior Court denied; the company appealed the denials on its motion in August 1982. The company eventually reached a settlement with the State on the $16.8 million default judgment. The State of California requested CERCLA funding for a remedial investigation/feasibility study to determine the nature and extent of contamination at the site and to identify alternatives for remedial action. In December 1982, the State of California requested that EPA propose Iron Mountain Mine for listing on the National Priorities List, and the site was listed in September 1983. In 1989, EPA issued an Administrative Order requiring the PRPs (Rhône-Poulenc (Aventis CropSciences USA, Inc.); Iron Mountain Mines, Inc.; and Mr. T. W. Arman) to implement emergency treatment of acid mine drainage discharges from the underground mines to minimize the contamination of adjacent water bodies. In 1990, EPA ordered the PRPs to implement a cleanup action in the Upper Spring Creek to divert clean water away from sources of contamination on the site. One year later, EPA ordered the PRPs to assume responsibility for operation and maintenance of the completed cleanup actions. In 1992, EPA ordered the PRPs to expand the existing emergency treatment operations and to construct a full-scale permanent treatment system for the Boulder Creek Watershed. This was followed, in 1994, by an EPA Administrative Order requiring the PRPs to implement the collection and treatment system for the acid mine drainage discharges at the Old Mine/No. 8 Mine. Finally, in 1997, EPA ordered the PRPs to design and construct the Slickrock Creek Retention Reservoir to collect the area source acid mine drainage discharges for treatment. In December 2000, the EPA, the U.S. Departments of Commerce and the Interior, and several California State agencies reached a settlement with Aventis, the principal responsible party at IMM. The total value of this settlement—for past costs and future work—is over $950 million. (Terms of the settlement are provided below in the Successes section.)

Photo 3: The view looking into the refurbished Richmond adit. The pipe used to convey acid mine drainage out of the mine is visible on the tunnel floor at left.

MINING IMPACTS

Nearly 100 years of mining activity at Iron Mountain left numerous waste rock and tailings piles, massive fracturing of the bedrock overlying the extensive underground mine workings and remaining sulfide deposits, sinkholes, seeps, and contaminated sediments in nearby waterbodies. The underground mine workings and the fractured bedrock above them provide an effective means for both water and air to reach the enormous sulfide deposits deep within the mountain, where water and oxygen react with the sulfide ores (mostly pyrite), producing sulfuric acid and dissolving the heavy metals in the ore. This is a classic recipe for acid mine drainage, which led one group of researchers to call Iron Mountain "a 'worst-case scenario' with respect to the formation of acid mine drainage." Most of the acid mine drainage comes from the oxidizing sulfides within the three largest sulfide ore bodies, the Brick Flat, Richmond, and Hornet deposits.

Members of the underground sampling team had to contend with dangerous conditions in the mine: temperatures over 120°F, humidity close to 100%, frequent rock falls from the 40-foot ceiling, and hot acidic water (more concentrated than battery acid) dripping everywhere.

In 2000, microbiologists conducting research inside Iron Mountain announced the discovery of a new species of iron-oxidizing Archaea (along with plants and animals, one of the three primary forms of life on Earth) that thrives in the extreme conditions found in the mine. This organism (christened *Ferroplasma acidarmanus*) grows on the surface of exposed pyrite ore in pools of water so acidic that they were previously thought to be inhospitable to all forms of life. It greatly accelerates the rate of oxidative dissolution of pyrite, the process that produces acid mine drainage by converting iron sulfide minerals to sulfuric acid. The discovery of *Ferroplasma acidarmanus* helps explain why the acid mine drainage problem at Iron Mountain is so severe. According to EPA, the uncontrolled discharge of copper and zinc from IMM is equal to about one-fourth of the entire national discharge of these two metals to surface waters from industrial and municipal sources.

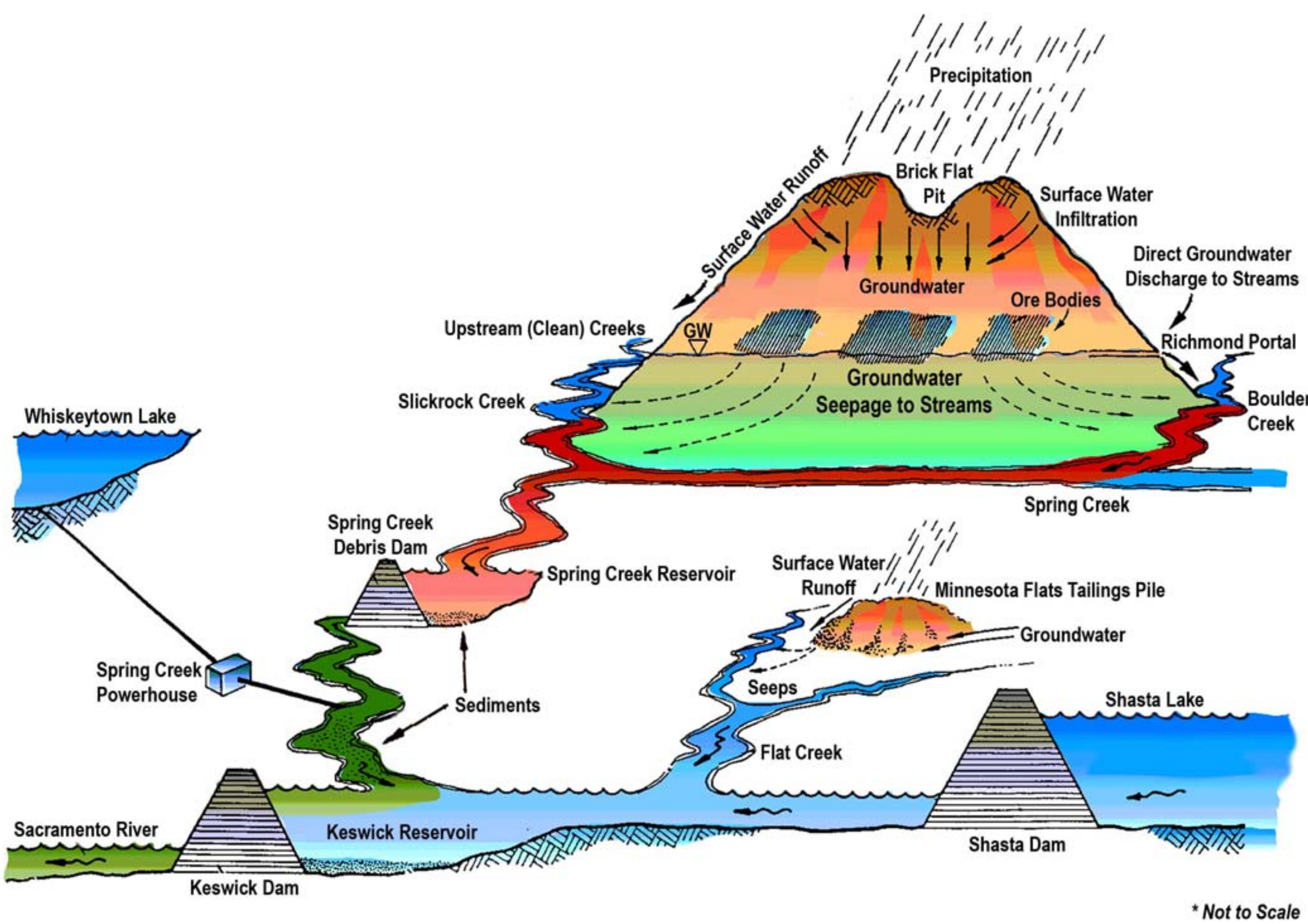


Diagram of Acid Mine Drainage at Iron Mountain Mine

Prior to EPA's cleanup of the site, most of the acidic effluent from Iron Mountain flowed or seeped out of the mines into adjacent streams and eventually into Keswick Reservoir, a run-of-river reservoir on the Sacramento River. Consequently, the creeks draining Iron Mountain are essentially devoid of aquatic life downstream (though not upstream) of the mines. The stretch of the Sacramento River just below Keswick Dam is among the river's most productive salmon spawning grounds and is also the location of the drinking water intake for the City of Redding. Fortunately, acid mine drainage from Iron Mountain poses no imminent threat to Redding's water supply due to the combination of dilution in the Sacramento River and removal of the metals in the city's water treatment plant. The City of Redding does, however, have a contingency plan to switch its drinking water supply to groundwater temporarily should a major release of metal-rich drainage from Iron Mountain occur.

Fish (especially young fish, known as *fry*) and other aquatic organisms are far more sensitive than humans to metals like copper, zinc, and cadmium. These metals act as chemical asphyxiants by binding to gill surfaces and interfering with the gills' ability to absorb oxygen. Even sub-lethal concentrations of toxic metals may harm aquatic organisms. Thus, the water-quality criteria for copper, cadmium, and zinc are considerably more stringent for aquatic life than for drinking water.

"When extraction of the ore was suspended from the various stopes above the Lawson, the ground was in very bad shape, and the conditions regarding heat and gas were so terrible that it seemed advisable to abandon any attempt to work from that level. In fact it was a case of walking away and leaving the job for the next generation" (William F. Kett, General Manager, Mountain Copper Co., August 1944).

The diverse sources of acid mine drainage and the occasional intense, high-runoff storm events characteristic of the area's climate historically resulted in major releases of heavy metals. During periods of heavy winter rain, high volumes of acid mine drainage are produced because more water flows through the mineralized zones and waste piles at IMM. Such high-flow events result in elevated levels of metals in the discharges of acid mine drainage: rather than diluting the base flows, the higher flow during storms apparently increases pyrite oxidation and dissolves soluble salts within the mine. In the past, heavy runoff from the Spring Creek drainage occasionally caused the Spring Creek Reservoir to overflow. One consequence was an accumulation of heavy metals in the sediments in Spring Creek and Keswick Reservoirs, downstream of the Spring Creek Debris Dam. In addition, the Federal Bureau of Reclamation typically restricts the outflow from Shasta Lake during heavy rains to prevent downstream flooding and to maximize water storage behind Shasta Dam. This reduces the dilution of metal-rich effluent from IMM entering the Sacramento River, and the combination of these events can raise dissolved copper concentrations in the Sacramento River to 13 parts per billion (ppb) while lowering the river's pH from its normal value of 7.5 to an acidic 6. A concentration of 13 ppb copper is sufficient to kill fish fry if the exposure lasts for several days, and research indicates that copper's toxicity to fish increases as pH decreases. In March 1992, at the height of the second-worst drought in California history, the Bureau of Reclamation was impelled to release 77,000 acre-feet of water from Shasta Lake to dilute a spill from Spring Creek Reservoir. At that time, Shasta Lake was only half full, and the water released from the reservoir (valued at $18 million) was badly needed by farmers in California's Central Valley.

Photo 4: The lime neutralization/high-density sludge acid mine drainage treatment facility at Minnesota Flats.

Photo 5: According to EPA documents, workers once inadvertently left a shovel standing in the green liquid flowing from one of the mine portals. The next day half of the shovel had been eaten away.

As early as 1900, the California Fish Commission investigated fish kills in the Sacramento River attributed to pollution from IMM, and in 1939 the State of California began studying the relationship between water quality and fish toxicity. State records document more than 20 fish-kill events in the Sacramento River downstream of IMM since 1963. Acid mine drainage from Iron Mountain killed 100,000 or more fish on separate occasions in 1955, 1963, and 1964; and at least 47,000 trout died during a one-week period in 1967. Among the aquatic organisms harmed by acid mine drainage from Iron Mountain are four runs of Chinook salmon, steelhead and other resident trout species, hundreds of species of aquatic insects, clams, mussels, plants, and single-celled algae. The U.S. Fish and Wildlife Service lists the winter-run and spring-run Chinook, which spawn in the Sacramento River near Redding, as endangered and threatened, respectively, pursuant to the Endangered Species Act.

For decades, eroded tailings and waste rock (along with acid mine drainage) have washed down Iron Mountain into Spring Creek, especially during large winter storms. After the completion of the Keswick Dam in 1950, the Spring Creek Arm of Keswick Reservoir began to fill rapidly with the debris eroded off Iron Mountain and the metals precipitating out of the acid mine drainage as it was neutralized in the reservoir. Nearly all the acid mine drainage is now collected and treated on-site, and movement of eroded tailings is largely prevented by the remedial actions taken to date at both the Slickrock Creek and the Spring Creek Debris Dams. Nevertheless, large quantities of contaminated sediments now rest on the bottom of Spring Creek and the Spring Creek Arm of Keswick Reservoir. Studies by the U.S. Geological Survey (USGS) and the California Department of Fish and Game document high concentrations of heavy metals in these sediments. The sediments in the Spring Creek Arm of Keswick Reservoir are located directly downstream of the discharge from the Spring Creek Hydroelectric Power Plant. Consequently, these sediments pose an ecological risk because power plant operations or a major storm event that causes Spring Creek Reservoir to fill and spill could scour the contaminated sediments in the reservoir, mixing them in the water column and exposing fish and other aquatic organisms downstream to the toxic metals.

Photo 6: Part of the lime neutralization/high-density sludge acid mine drainage treatment plant at Minnesota Flats. The large tank at center-left is one of two in which acid mine drainage is mixed with lime slurry.

Photo 7: The sludge conditioning tank at Iron Mountain Mine is one of the largest in the world. The sludge is periodically transferred to the drying beds visible behind the tank before being placed in a disposal cell on the site.

In addition to the abandoned mine workings, mine tailings are another source of acid mine drainage. The Minnesota Flats area, on the east flank of Iron Mountain, was the site of a mill where ore was crushed and processed. The legacy of that refining process was a large tailings pile. In 1989, EPA removed those tailings to a disposal cell near the top of Iron Mountain, and in 1994 a water treatment plant was built at Minnesota Flats. This facility, which has been expanded and upgraded since it was first constructed, uses lime (calcium oxide, CaO) to neutralize the acid mine drainage collected from several sources, including the Richmond and Lawson portals, the Old/No. 8 Mine seep, and the Slickrock Creek Reservoir. The acid mine drainage from these various sources is transported to Minnesota Flats via more than three miles of pipeline. In the treatment plant, the acidic effluent is thoroughly mixed with a lime slurry. The process not only neutralizes the acid, it also causes the metals to precipitate out of solution, removing over 99% of the copper, zinc, cadmium, and other metals. The mixture is then conveyed to a large sludge conditioning tank, where the resulting high-density sludge settles to the bottom. Periodically, the sludge is removed from the tank and deposited in beds adjacent to the treatment facility, where it is allowed to dry before being trucked to the disposal cell in the pit at Brick Flat.

Putting the IMM Problem in Perspective:

The acid mine drainage from IMM is among the most acidic and metal-laden anywhere on Earth. Prior to EPA's cleanup, the heavily worked mines on Iron Mountain discharged, on average, 650 pounds of copper, 1,800 pounds of zinc, and 10,000 pounds of iron per day. For comparison:

1. The IMM discharge was at least equal to all the combined industrial and municipal discharges to the San Francisco Bay and Delta Estuary System.
2. The IMM discharge was more than twice the combined discharge from the 28 largest inactive mines in Northern California. The next largest was less than one-tenth of the IMM discharge.
3. The IMM discharge was equal to about one-fourth of the entire national discharge of copper and zinc to surface waters from industrial and municipal sources.
4. The IMM discharge was the largest discharge to surface waters in the nation identified under the Clean Water Act (CWA) §304(l) program for cleanup of impaired waters of the United States.

Mining activities also left a large deposit of pyrite ore at the end of an aerial tram that used to move the ore from the Richmond Mine and the open pit mine at Brick Flat to the Matheson Rail Loading Station, where the ore was loaded onto trains for shipment. In addition to contributing to water pollution, the ore posed a risk of direct human exposure to the arsenic, lead, cadmium, and other toxic metals contained in the ore. In response, in 2005, EPA excavated and removed approximately 7,600 cubic meters (10,000 cubic yards) of soil contaminated with pyrite ore, along with old concrete bunkers and other debris from the three-acre site. The material removed from the Matheson site was placed in a disposal cell on Iron Mountain. The site, located on the shores of Keswick Reservoir, may now be enjoyed by the public.

At present, acid mine drainage still escapes untreated from waste piles and seepage on the north side of Iron Mountain and flows into Boulder Creek. EPA continues to investigate and plan future actions to control acid mine drainage in the Boulder Creek catchment.

EPA's Cleanup Objectives for Iron Mountain

EPA's primary objectives for IMM are to:

1. Reduce—and, if possible, eliminate—acid mine drainage and the mass discharge of toxic heavy metals harmful to human health and the environment through application of best available control technologies.
2. Comply with water quality criteria established under the CWA in locations where species may be exposed to the toxic metals and acid mine drainage.
3. Minimize the need to rely on California's scarce and valuable water resources to meet the water quality criteria.
4. Encourage the continued development and evaluation of source control and resource recovery technologies that may someday reduce or eliminate the discharges and the need to operate the treatment plant.

SUCCESSES

Listing Iron Mountain Mine on the National Priorities List was key to the success of this project, as listing gave EPA access to CERCLA funding (Superfund). EPA's Remedial Project Manager (RPM) at IMM for the past 17 years emphasizes the importance of Superfund monies in allowing the Agency to proceed with needed work in a timely fashion and without having to wait for legal settlements or decisions. Because of Superfund, EPA was able to step in and pay to do things "the right way" when work was delayed by negotiations or cleanup decision disputes. Two illustrative examples cited by the RPM are the construction of the lime neutralization/high-density sludge water treatment plant at Minnesota Flats and the reconstruction of a bridge over Spring Creek that was washed out by extremely heavy rains on New Year's Day 1997, thereby preventing access to the site.

Integral to the success of the cleanup was the relationship among EPA, other Federal agencies, and the State of California. Specifically, the timely and effective support of California's Department of Toxic Substances Control (DTSC) in mobilizing enforcement support resources was critical in the overall cleanup effort.

In December 2000, the EPA, Department of the Interior, Department of Commerce, and several California State agencies reached a settlement with Aventis, the principal responsible party at IMM. The total value of this settlement—for past costs and future work—is over $950 million. Under the terms of the settlement, Aventis provided, through an insurance instrument held by American International Group, Inc. (AIG), $200 million for the first thirty years of site activities, $100 million in cost overrun insurance, plus a balloon payment of $514 million in 2030, which the EPA or State of California may use to fund future activities. The settlement also involved an $8 million payment to EPA for future site costs, a $10 million payment for natural resource restoration projects, such as wetlands restoration, and an agreement by Aventis not to seek compensation for $150 million in past project costs. This settlement is noteworthy for two principal reasons. First, it was one of the largest settlements with a single private party in Superfund history. Second, the long time-horizon of the settlement is crucial to the continued success of the Iron Mountain cleanup. Unless researchers eventually figure out an effective and reliable way to prevent the formation of acid mine drainage at Iron Mountain, the lime-neutralization/HDS water treatment plant will have to continue operating for a *very* long time. USGS scientists estimate that at current erosion rates, Iron Mountain will continue to produce acid mine drainage for 2,500 to 3,000 years, until the estimated 12 million tons of sulfide deposits remaining within the mountain have weathered away.

Cleanup partners

- Bureau of Land Management
- Bureau of Reclamation
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Fish and Wildlife Service (FWS)
- U.S. Geological Survey (USGS)
- California Central Valley Regional Water Quality Control Board
- California Department of Fish and Game
- California Department of State Lands
- California Department of Toxic Substances Control (DTSC)
- CalTrout

A key factor in facilitating agreement to a settlement with Aventis was making a convincing case that the observed damage to the aquatic ecosystems downstream of the mines at Iron Mountain can be causally linked to the mining activities at the site and that the natural weathering of Iron Mountain did not result in similar effects even before the advent of mining. There were two facets of this case. The first was the observation that Spring Creek, Boulder Creek, and Slickrock Creek support healthy ecosystems upstream of the mines. The population of fish and other organisms would not have been able to migrate upstream through the stretches of water affected by acid drainage to colonize the upper reaches of these streams if Iron Mountain had been releasing recently-observed quantities of acid and metals for millennia. The second facet of this case involves estimating the rate at which the sulfide deposits at Iron Mountain have weathered naturally over time. This was accomplished by estimating the original quantity of sulfide ore and the latest (i.e., most recent) date for which sulfide weathering could have begun. The essential point here is that, for a given original quantity of sulfide ore, the later the onset of sulfide weathering, the greater the rate of that weathering and consequently the higher the resulting acidity and concentrations of metals in the adjacent streams. The gossan outcrop at Iron Mountain is the result of the weathering of exposed sulfide deposits. The rust-red color of the gossan derives from the oxidized iron that makes up a large portion of the material (the sulfide deposits within Iron Mountain are approximately 95% pyrite). By dating the start of sulfide weathering (i.e., gossan formation), one obtains an estimate for the duration of sulfide weathering. And by dividing that figure into the estimated total quantity of sulfide ore believed to have weathered during that time, one obtains an estimate of the rate of weathering and the rate of release of acid and metals to adjacent streams. Because of the high iron content of the gossan, USGS scientists were able to use paleomagnetic techniques to establish a minimum age for the gossan of 780,000 years. This minimum age value means that, even assuming a conservatively large original quantity of sulfide ore at Iron Mountain, the pre-mining flux rates of metals at Iron Mountain were 25 to 300 times lower than those observed since Iron Mountain was mined. The partnership between EPA and USGS was essential to this bit of geological detective work.

Photo 8: Gossan (rust-colored, oxidized iron ore) outcrop near the summit of Iron Mountain.

EPA's plan for Iron Mountain encourages the continued development and evaluation of source control and resource recovery technologies that may someday reduce or eliminate the discharges and the need to operate the treatment plant.

As two USGS scientists working at Iron Mountain put it, "the effectiveness of a remedial alternative usually cannot be easily quantified or predicted. Hence, we must admit that remediation is experimental." Cleanup activities on the scale of Iron Mountain typically comprise both short-term and long-term objectives, and while it is ideal if short-term solutions also contribute to achieving long-term ends, that is not always possible. In the case of Iron Mountain, achieving the short-term goal of protecting human and ecosystem health by collecting and treating the acid mine drainage does nothing to achieve the long-term goal of eliminating the source of the acid mine drainage, whereas removing tailings piles and contaminated sediments and capping subsidence areas on the mountain may serve long-term ends. But despite years of investigation and consideration of many possible alternatives (e.g., strip mining Iron Mountain in its entirety, mining out the remaining sulfide ore, or sealing the mine portals and flooding Iron Mountain with water or an inert gas), it remains unclear whether there is a good, permanent solution to the problem. As such, one of the great successes of the efforts to date has been the application of an iterative approach: implementing low-risk and low-cost options while studying the options and planning next steps.

APPLYING IMM ACHIEVEMENTS TO OTHER SITES

Photo 9: The recently completed Slickrock Creek Dam captures acid mine drainage escaping from fractured bedrock and buried mine portals along the south side of Iron Mountain. The water in the reservoir is transported by pipeline to the treatment plant at Minnesota Flats.

Over the past 25 years, there have been truly dramatic improvements in the conditions at the IMM site, in the creeks that drain the mountain, and in the Keswick Reservoir and Sacramento River farther downstream. Site cleanup and pollution control measures—in particular, the acid mine drainage collection and treatment systems—now intercept 95 percent of the historic quantities of copper, cadmium, and zinc discharged from Iron Mountain and neutralize the associated acidity. Further, the Slickrock Creek Dam and other engineered structures should prevent the uncontrolled release of acid mine drainage from Iron Mountain in all but the most severe storms. This success not only helps guarantee the protection of a safe drinking water supply for the City of Redding, it goes a long way toward safeguarding the viability of threatened and endangered salmon and trout species in the Sacramento River and the river's aquatic ecosystem as a whole. The achievements at Iron Mountain are the result of a number of important factors, including:

1. The use of Superfund monies to implement pollution control measures in a timely manner while making efficacy—not low price—the paramount criterion;

2. A financial settlement with the PRPs that provides for the operation and maintenance of the on-site treatment facilities far into the future;

3. Effective partnerships among Federal, State, and local stakeholder groups;

4. A highly skilled and motivated technical team comprising experts from within EPA, other Federal agencies, State agencies, and contractors with mastery of the full range of technical issues posed by complex Superfund sites;

5. An iterative approach to site cleanup that involved starting simply and implementing low-cost, low-risk controls while studying and preparing next steps;

6. The effective use of a combination of Superfund and enforcement tools; and

7. Valuable research on the causes of acid mine drainage—including the discovery of a new species of iron-oxidizing microorganism.

Many, if not all, of these success factors are potentially applicable to other Superfund sites and to other metal sulfide mine and mineral processing sites around the country and the world.

SITE TIMELINE

1860s	Land surveyor William Magee discovers massive iron ore deposit (gossan outcropping) in the Spring Creek basin.
1879	Silver is discovered in gossan and mining begins.
1894	Mountain Mines Ltd. of London, England buys the property; name subsequently changes to Mountain Copper Co.
1895 – 1896	Underground mining begins with the discovery of copper sulfide ore below gossan in Old Mine workings; ore is shipped to smelter built at Keswick (on the site now occupied by the Spring Creek Powerhouse adjacent to the Keswick Reservoir) via an 18 km, narrow-gauge railway
1899 – 1900	California Fish Commission investigates periodic fish kills in the Sacramento River attributed to pollution from Iron Mountain Mine.
1902	U.S. Forest Reserve sues company for vegetation damage from smelting activities.
1904	Keswick smelter hits peak operation, processing 1,000 tons of ore daily.
1907	Local smelting at Keswick is phased out and ore is henceforth transported to Martinez, California for processing.
1907	No. 8 ore body is discovered below Old Mine; Hornet Mine opens on Boulder Creek.
1914	Minnesota Flats flotation mill is constructed—first flotation plant in California.
1920 – 1943	Crushing and screening plant operates near Hornet Mine.
1928 – 1942	Gossan is mined by open pit method at Brick Flat; 600 tons of ore treated daily at cyanide plant on Slickrock Creek to extract gold and silver.
1931	Minnesota Flats mill closes.
1928	California Fish and Game Commission files complaint regarding tailings dam.
1939	State initiates studies of water quality and fish toxicity.
1943	Construction of Shasta Dam, upstream from Iron Mountain outflows, is complete, reducing dilution of polluted discharges from Iron Mountain to the Sacramento River.
1944	Copper cementation plant is built on Boulder Creek to remove copper from water discharged from Richmond and Lawson (Hornet Mine) portals.
1950	Construction of Keswick Dam, downstream from Iron Mountain outflows, is complete.
1955	Large landslide from mine waste pile fills Slickrock Creek canyon to a depth of 24 m, covering portals to Old Mine and No. 8 Mine.

1955 – 1962	Open pit mining of pyrite occurs at Brick Flat for sulfuric acid production.
1963	Construction of Spring Creek Debris Dam is complete, regulating outflow of acid mine waters to the Sacramento River and preventing sediment from filling Keswick Reservoir.
1967	Stauffer Chemical Company acquires property.
1976	State of California adopts regulations making owners of inactive mine sites responsible for meeting Federal Clean Water Act standards for pollution; Iron Mountain Mines, Inc. acquires property.
1976 – 1982	State of California fines owners for unacceptable releases of metals.
1977	Copper cementation plant is constructed on Slickrock Creek to remove copper from water discharge and Old and No. 8 Mines seep.
1983	IMM is listed on National Priorities List (NPL) for EPA Superfund, ranking as the third largest polluter in the State of California.
1986 – 1997	Four Records of Decision (RODs) by EPA require several remedial activities, including partial capping; surface-water diversions; tailings removal; and lime neutralization treatment of the most acidic, metal-rich flows, reducing copper and zinc loads by 80 to 90%.
1988 – 1994	Operation of an emergency treatment plant through the wet season of each year significantly reduces the discharge of heavy metals from Iron Mountain by partially treating the discharges from the Richmond and Lawson portals, the most concentrated acid mine drainage discharges at the site.
1989	EPA completes a series of remedial actions authorized in the 1986 ROD: removal of tailings from the Minnesota Flats area, capping in Brick Flat pit, and capping of several subsidence areas.
1990	EPA completes the diversion of uncontaminated flow in upper Slickrock Creek around a large waste pile.
1991	EPA completes the diversion of clean water in upper Spring Creek, which now flows to Keswick Reservoir via Flat Creek.
1994	Rhône-Poulenc (one of the responsible parties at the site) completes construction of a lime neutralization treatment plant at Minnesota Flats for the acid mine drainage collected from the Richmond and Lawson portals. The treatment process neutralizes the acid mine drainage and traps the toxic metals in a high-density sludge (HDS). Completion of the consolidation and capping of seven pyritic waste piles that were discharging acid mine drainage and eroding into Boulder Creek. Completion of a system to collect and convey the Old and No. 8 Mines seep flow to the lime neutralization/HDS treatment plant at Minnesota Flats.
1996	EPA completes construction of the onsite HDS landfill in Brick Flat pit.

2000	EPA, the State of California, Aventis CropSciences USA, Inc. (corporate successor to Mountain Copper Ltd. and Stauffer Chemical Co.) and Stauffer Management Co. (indemnitor to Aventis) reach a settlement agreement. Under the settlement, the PRPs provide funding to ensure that the treatment plant, "the heart of the IMM remedy," will continue to operate in perpetuity.
2002	EPA implements additional remedial activities, including diverting and treating water from Slickrock Creek, bringing overall load reduction of copper and zinc to 95%.
2004	Construction of the Slickrock Creek Dam is complete, resulting in 95% overall load reduction of historic copper, cadmium, and zinc discharges.
2005	Mine wastes (pyrite ore) are removed from the Matheson Rail Loading Station site on the banks of Keswick Reservoir.
2007	Dredging of contaminated sediments to occur in the Spring Creek Arm of Keswick Reservoir.

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