APPENDIX A

MINING INDUSTRY PROFILE

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1. OVERVIEW

This overview provides summary information on 11 commodities (10 non-fuel and uranium) that are produced from the most important metalliferous and fertilizer ores in the United States. The combined value of these minerals (copper, gold, iron ore, lead, molybdenum, phosphate rock, platinum, potash, silver, uranium, and zinc) was $12.15 billion in 1993, accounting for less than 1 percent of gross national product (GNP) (U.S. Department of Commerce, 1994).

This appendix is intended to provide an *overview* of mining activities and the mining industry, not a comprehensive examination. It is necessarily simplistic, but should give a snapshot of the industry as it existed in 1992. This framework recognizes the dynamic nature of this vital industry and the market, technological, and other factors that drive its performance, environmental and otherwise.

These metals and minerals are the primary raw materials used in many industrial applications and thus are essential to the American and world economies. Copper, for example, is essential to the electronics and construction industries, while iron ore provides the base material for the steel, automotive, and transportation industries. Molybdenum is used in steel production, machinery, electrical and chemical manufacturing. Potash and phosphate rock are used in fertilizers and chemical manufacturing. Gold, while primarily used in jewelry and the decorative arts, is also used in the electronics industry and dentistry. Table 1 provides a more detailed list of the consumptive uses for these minerals.

The minerals industry also contributes to the national economy by virtue of its production of exports and its reduction of industrial dependence on certain minerals that the United States would otherwise import. For example, the U.S. exports 8% of the lead and 75% of the molybdenum it produces. Conversely, the U.S. imports 22% of the iron ore it consumes (Bureau of Mines, 1995). See Table 2 for detailed national production data (including import and export information) for these minerals.

The extraction and beneficiation of these minerals necessarily lead to the generation of large quantities of waste. Total waste (waste rock and tailings) produced during the extraction and beneficiation of minerals can range from 10% of the total material removed from the earth (potash) to more than 99.99% (gold). As for total amounts of waste generated in 1992, the gold mining industry generated about 540,661,000 metric tons and the copper mining industry generated 731,065,000 metric tons; potash, on the other hand, generated 197,000 metric tons (Bureau of Mines, 1992a). To put these quantities in perspective, about 200,000,000 metric tons of municipal solid waste are generated in the United States each year.

TABLE 1. Number of Mines, Total Production and Uses of Commodities of Concern, 1992

Commodity	Number [1]	Major uses	Total U.S. mine production (metric tons)	Production as % of consumption
		Building construction, electrical and electronic products, Industrial machinery and equipment, transportation equipment, and consumer and general products		75%
				300%
		Transportation (batteries, fuel tanks, solder, seals, and bearings); electrical, electronic, and communications uses		74%
		Iron and steel production, machinery, electrical, transportation, chemicals, and oil and gas industry uses		32%
				287%
Platinum group metals				109%
				12%
		Photographic products, electrical and electronic, electroplated ware, sterlingware, and jewelry		32%
				NA

NA

41%

NOTES:

co-products or by-products from other commodity mining operations (e.g., gold as a result of copper production). Therefore, the number of mines for individual commodities includes both actual commodity mines and those mines from which the commodity is a co-product or by-product. These uncertainties result in inconsistent numbers throughout the BOM sources.

Sources:

TABLE 2. National Mining and Beneficiation Data (by Commodity), 1992

Commodity	Number [1]	Value of Commodity Produced ($1,000,000)	Total Commodity Produced (1,000 mt)	Tailings [2] (1,000 mt)	Waste Handled Other (1,000 mt)	Number of Employees	(Value of Commodity Produced/GDP)	Consumption (1,000 mt) Exports (% of Total	Imports (% of Total
								4	5
									593 (34%)
									0.174 (53%)
									12,230 (22%)
									5 (1%)
Platinum group metals									3 (6%) 1,530 (3%) 132 (1,588%)
									4,227 (248%)
						682 (person			4.9 (277%)
						years)			NA

45 (9%)

products from other commodity mining operations (e.g., gold as a result of copper production). Therefore, the number of mines for individual commodities includes both actual commodity mines and those mines from which the commodity is a co-product or by-product. These uncertainties result in inconsistent numbers throughout the BOM sources.

2. LOCATION OF MINING ACTIVITIES

Tables 3 and 3a show the distribution of hardrock mining activities in the United States (1992 Bureau of Mines data for number of mines and state-by-state production for each commodity). The following discussion briefly summarizes location information for each sector. The information presented below focuses on primary production. However, significant volumes of some minerals are produced as byproducts (e.g., molybdenum as a byproduct of copper flotation). For the purposes of this discussion, primary production refers to the major mineral extracted at the mine. Byproducts are the ancillary minerals that are found in and recovered from the same ore as the primary mineral, although the presence of that byproduct is not the primary target.

Copper. As shown in Tables 3 and 3a, southern and central Arizona copper mines produce nearly two-thirds of U.S. copper. Among other primary copper producers, several large copper mines are located in New Mexico near the Arizona border (close to smelter facilities) and one of the largest copper mines in the country, Kennecott Utah Copper, is located near Salt Lake City. An additional medium-size underground mine, Copper Range's White Pine facility, is near Lake Superior on the Upper Peninsula of Michigan. The copper mines in other states identified in Table 3 either are small operations or represent limited byproduct production at gold, molybdenum, and other mines (Bureau of Mines, 1992a, 1992b, and 1995; EPA, 1994a).

Gold. With the widespread application of heap leaching technology, most of the U.S. gold production now occurs in Nevada. Nevada mines account for more than 60 percent of the total production, with most mines located along the Carlin Trend in northwestern Nevada. Most other gold mining operations are located throughout the western United States, including Alaska, although four gold mines are located in South Carolina (Bureau of Mines, 1992a; 1992b; EPA, 1994c).

Iron. Nearly all of the iron mined in the United States is produced from taconite ore found in Northern Minnesota and Michigan. The largest mining operations (all open pits) are found along the Mesabi Range in Minnesota, which extends from Hibbing to north of Duluth (Bureau of Mines, 1992a; 1992b; EPA, 1994f).

Lead/Zinc. The Viburnum area of southeastern Missouri is the center of U.S. lead production. The lead mines in this area also produce significant quantities of zinc (as a byproduct from smelter operations). Alaska is the largest zinc producer in the United States (with associated lead byproducts) at the Red Dog and Greens Creek Mines (the Red Dog Mine is the primary producer). Central Tennessee and northern New York State are also major sources of zinc ore (Bureau of Mines, 1992a; 1992b; EPA, 1994g).

TABLE 3. Location of Mining Activities, 1992

State									Phosphate Rock	
	#[1]	% U.S. Production	#[1]	% U.S. Productio	#[1]	% U.S. Production	#[1]	% U.S. Production	#[1]	% U.S. Production
		1,765,000 metric tons		n 329 metric tons		55,593,000 metric tons		308,000 metric tons		46,965,000 metric tons
								15.6%		
								W		
						W				
								W		
										68.6%
										11.1%
								W		
						23.2%				
						76.2%				
								75.6%		
										NA
				61.7%						
								W		
							2			
										W
				W						
				2.1%						
						W				
								W		

W

TABLE 3. Location of Mining Activities, 1992 (continued)

State	#	% U.S. Production	#	% U.S.	'	% U.S. Production	#	% U.S. Production	Phosphate Rock #	% U.S. Production
		1,765,000 metric tons		metric tons 329		55,593,000 metric tons		308,000 metric tons		46,965,000 metric tons
										NA
				W						

NOTES:

W

or by-products from other commodity mining operations (e.g., gold as a result of copper production). Therefore, the number of mines for individual commodities includes both actual commodity mines and those mines from which the commodity is a co-product or by-product. These uncertainties result in inconsistent numbers throughout the BOM sources.

SOURCES:

NA = Information not available.

W = Information withheld by the Bureau of Mines for proprietary reasons.

TABLE 3a. Location of Mining Activities, 1992

State	#	% U.S. Production	#	% U.S. Production	#	% U.S. Production	#	% U.S. Production	#	% U.S. Production	# Zinc	% U.S. Production
		49,000 metric tons		8,300 metric		1,705,000 metric tons		1,800 metric		922 metric tons		524,000 metric tons
				tons				tons				
												47.5%
								9.2%				
								1%				
												NA
										NA		
												NA
												NA
								NA				
								1.8%				
												8.4%
												3.9%
										35%		
								34.1%				
										10%		
North Carolina												W

.06%

State	#	% U.S. Production	#	% U.S. Production	#	% U.S. Production	#	% U.S. Production	#	% U.S. Production	# Zinc	% U.S. Production
		49,000 metric tons		8,300 metric		1,705,000 metric tons		1,800 metric		922 metric tons		524,000 metric tons
				tons				tons				
								NA				
								0.3%				
(continued)												W
										NA		
Vermont										NA		
												NA

NOTES:

5

products from other commodity mining operations (e.g., gold as a result of copper production). Therefore, the number of mines for individual commodities includes both actual commodity mines and those mines from which the commodity is a co-product or by-product. These uncertainties result in inconsistent numbers throughout the BOM sources.

three true molybdenum mines, two are located in Colorado and one in Idaho.

SOURCES:

Phosphate Rock. The Tampa/Bartow area of central Florida is the major phosphate rock producing area of the United States. The recent introduction of a heavy media separation process at IMC's Four Corners mine has led to possibly increased phosphate recovery from types of ore that previously could not be beneficiated (i.e., the potential for additional production in the area). Beyond the Florida operations, TexasGulf operates a large phosphate facility along the North Carolina coast near New Bern, and smaller phosphate mines are located in Idaho, Montana, and Utah (Bureau of Mines, 1992a; 1992b; EPA, 1994h).

Molybdenum. Recent market conditions have limited molybdenum production in the United States, especially primary production. In 1994, Cyprus' Henderson Mine in central Colorado was the only active primary molybdenum operation in the country (compared with three in 1992). Byproducts represent the remainder of U.S. production, mostly as a byproduct of copper ore flotation at mines and mills in Arizona and Utah (Kennecott) (Bureau of Mines, 1992a and 1992b).

Platinum. Only one platinum mine is active in the United States, the Stillwater Mine operated by the Stillwater Mining Company near Nye, Montana (Bureau of Mines, 1992a and 1992b).

Potash. New Mexico produced almost all potash produced in the United States in 1992. In the state, five producers operated six mines, all of which mined potash in underground bedded ore zones. The other potash-producing states (California, Michigan, and Utah) produced potash by two-well solution mining, solar evaporation, and selective crystallization (Bureau of Mines, 1992a and 1992b).

Silver. Silver is mined primarily in the Western United States both through primary and byproduct production. Primary silver production generally occurs in Montana, Idaho, and Nevada. Silver is also recovered as a byproduct from copper, lead/zinc, and gold production. In Alaska, silver is a significant byproduct at the Green Creek and Red Dog Mines. In Nevada, much of the total silver production is derived as a byproduct of the state's extensive gold mining industry (Bureau of Mines, 1992a and 1992b; EPA, 1994 and 1994c).

Uranium. The total amount of uranium produced in 1992 (522 metric tons) was more than 70 percent less than the quantity produced in 1991 and the lowest amount produced since 1951. The decreased demand for uranium (and the resulting decrease in price) shut down several mines and put others on standby. According to the Bureau of Mines, Nebraska produced nearly 35 percent of the uranium produced in the United States. Texas was second producing more than 12 percent. Of the 17 mines in operation in 1992, five were conventional mines (both underground and open pits), four were *in situ*, and eight were reported as "other" (heap leach, mine water, mill tailings, or low-grade stockpiles). In Florida, uranium has also been produced as a byproduct of phosphoric acid production (Bureau of Mines, 1992a and 1992b; EPA, 1994 and 1994j; U.S. Department of Energy, 1993).

3. MINING PRACTICES AND PRODUCTS

Overall, as shown in Table 4, hardrock mining operations handle large quantities of material, the vast majority of which becomes waste in most industry sectors. Although it varies by commodity, the amount of product per ton of ore is generally very small for most of these commodities. Overall, the quantities and characteristics of the wastes are largely beyond the control of the industry, since they are the direct product of the material being mined.

Conventional underground and surface mining techniques account for most of the hardrock mining in the United States. Until recent decades, nearly all mining occurred underground, but with the advent of large earthmoving equipment and cheaper energy sources, surface mining has become prevalent in most industry sectors. The relatively lower cost of surface mining has allowed much lower-grade ores to be exploited economically in some industry sectors (EPA, 1994). In addition, *in situ* leaching has been used for about two decades in uranium and copper mining.

Primary iron and phosphate ores are mined almost exclusively by surface mining methods. Open pit mining is also the predominant extraction method used in primary gold and copper production, although there are several significant exceptions. For example, Homestake's facility in Lead, South Dakota, and Copper Range's White Pine mine in Michigan are large underground gold and copper mines, respectively. An additional mining practice used during the past 20 years in the copper and uranium sectors is *in situ* leaching. Lead/zinc and the only platinum mine in the United States, on the other hand, are industry sectors where nearly all primary production occurs at underground mines (Bureau of Mines, 1993; 1992a; 1992b).

The major wastes generated by mines include mine water, waste rock, tailings, and overburden. Mine water is produced when the water table is higher than the underground mine workings or the depth of an open pit surface mine. When this occurs, the water must be pumped or drained out of the mine. Alternatively, water may be pumped from wells surrounding the mine to create a cone of depression in the ground water table, thereby reducing infiltration. Mine water may be used in milling operations as makeup water, used for dust suppression, or discharged. When mining ends and pumping stops, groundwater will usually recover to its pre-mining level, although this can take decades or centuries.

Surface mines generate greater volumes of waste rock than underground operations. Waste rock is typically managed in angle-of-repose piles, either within or near the pit/mine. Waste rock also can be used on-site for road construction, in tailings dams, and to backfill mined-out areas. The differentiation between waste rock and ore (i.e., the cutoff grade) is generally an economic distinction, and can vary significantly over time depending on economic conditions; thus, what is disposed as waste rock (or sub-ore) at one time during a mine's life may be ore at another time. In addition, the development of new technologies can lead to economically viable mineral recovery from historic waste rock piles. Sub-ore is often stored in freestanding piles until economic conditions favor its beneficiation or until the mine reaches the end of its active life (EPA, 1994). Waste rock piles are generally designed to drain freely

TABLE 4. Solid Waste Generated by Mines, 1992

Commodity	**Material [1] (thousand metric tons)**	**Thousand metric tons [2]**	**% of**	**Thousand metric tons**	**% of**	**Thousand metric tons Product**	**% of**	**(waste rock + tailings) Total waste Thousand metric tons**	**% of [4]**
									99.8%
				Ore					99.99%
									77%
Molybdenum, Platinum group									94.1% 99.5%
									69.1%
									10%
									99.9%
									NA
									89%

NOTES:

to minimize the potential for unstable conditions. Therefore, these piles are often located in natural drainages and now frequently have drainage systems installed during construction (e.g., French drains). Due to the potential for contamination of water flowing over or through waste rock piles, many mining facilities are now installing systems or taking steps to prevent or reduce the infiltration of precipitation. Contamination from piles may include sediments and solids, and also acid mine drainage or toxic pollutant loadings, depending upon the mineralogy of the waste rock. Systems used to reduce or prevent drainage into, or over, waste rock piles include uphill diversions, sloped and compacted surfaces, drains, and covers (EPA, 1994).

Except for the gold and copper sectors, in which leaching is increasingly prevalent, beneficiation of most other metal and phosphate ores occurs by conventional milling technologies. These include crushing, grinding, autoclaving, roasting, chlorination, calcining, and reagent flotation, by which a chemical reagent causes the target mineral to stick to air bubbles. In these cases, the ore is crushed and ground and the target mineral(s) are recovered, leaving very fine "tailings" as a waste to be disposed of. Tailings can be dewatered and disposed of in piles or used as backfill in the mine; more commonly, they are pumped as a slurry (typically 30 to 65 percent solids) to impoundments. In tailings impoundments, the solid component of the tailings settles out behind embankments and the ponded water is either reused in the process or discharged to surface water. The volumes of water discharged and reused are dependent on site-specific conditions, including water availability and evaporation rates. Tailings embankments/dams can be constructed of concrete, earthen materials, and/or waste rock or tailings (EPA, 1994 and 1994e; Bureau of Mines, 1995).

Table 5 is a summary of mining methods and beneficiation waste management practices for the various industry sectors.

While conventional flotation involves a wide range of flotation reagents (oils, xanthates, lime, etc.), depending on the industry sector and site-specific geology residual reagents comprise a diminishing fraction of the total amount of waste. One exception is in the phosphate industry where flotation occurs in conjunction with "washing" stages that use both ammonia and sulfuric acid; even there, at least one company now uses a substitute reagent that both increases recovery efficiency and reduces the toxicity of discharges (EPA, 1994 and 1994h).

Cyanidation technologies, some of which have been available for more than 100 years, are widely used for gold beneficiation. Higher-grade ores ("higher-grade" is relative; the highest grades are generally in the tenths of an ounce of gold per ton of ore) are crushed and ground, then the ore slurry passes through a series of tanks or vats that contain a sodium cyanide solution that dissolves the gold values; then the gold is recovered from the solution via Merrill-Crowe zinc precipitation or carbon adsorption, electrowinning, melting, and refining. The slurry of fine tailings is then disposed of, typically in impoundments (EPA, 1994, 1994c, and 1994i).

TABLE 5. Predominant Mining Methods and Waste Management Practices

Commodity	**Number of** [1]		**Predominant Beneficiation Methods**	**Major beneficiation waste management practices**
				Tailings impoundments
				Tailings impoundments, spent ore dumps
				Tailings impoundments
		Most open pit Several underground		Tailings impoundments (tank, vat), dumps and heaps (heaps), spent ore dumps
				Tailings back into mine cut
		Underground Open pit		Tailings impoundments
				Tailings impoundments
				Backfilling and clay ponds
				Tailings impoundment
		Underground, solution mining, lake brine	Flotation, heavy media separation, dissolution - recrystalization	
		Open pit, underground, placer, by-product	Flotation (base metal ores), Smelting (copper ores), Cyanidation (gold/ silver ores), precipitation (silver ores)	Tailings impoundments Tailings used as backfill

Note:

products or by-products from other commodity mining operations (e.g., copper as a result of gold production). Therefore, the number of mines for individual commodities includes both actual commodity mines and those mines from which the commodity is a co-product or by-product. These uncertainties result in inconsistent numbers throughout the BOM sources.

Source: Various

Lower grade gold ore (down to two hundredths of an ounce of gold or less per ton of ore), which may be crushed, is piled onto lined "pads," and a "barren" cyanide solution is applied to the surface. The cyanide solution percolates through the heap, dissolving gold values. This "pregnant" solution is recovered from the base of the heap, gold is recovered from the solution, and the "barren" solution is refortified with cyanide and reapplied. The pregnant and barren solutions are generally stored in lined ponds. Following leaching, spent ore may either be left in place (with new ore added over it) or removed for disposal (after detoxification/neutralization) in a spent ore pile/dump. Where spent ore is managed in place, neutralization of the residual cyanide occurs after the heap has reached the maximum height (EPA, 1994, 1994c, and 1994i).

The process of using cyanide to extract gold works most effectively on oxide ores. (Oxide ores are those exposed to weathering and the action of water, and that have little or no sulfur content.) As the sulfur content of the ore increases, the efficiency of gold recovery decreases. As shallow oxide deposits are mined out, gold mines are beginning to extract ores with ever higher concentrations of sulfur bearing minerals. In response, operators are treating these sulfide ores with a variety of techniques to reduce their sulfur content. Such techniques include roasting and biological treatment. The trend towards greater exploitation of sulfide ores is of concern in that these ores contain potentially acid generating sulfide minerals, as does the waste rock (EPA, 1994c and 1994i).

In addition, copper ores are increasingly being leached, primarily in very large dumps (e.g., Cyprus Minerals Col, ASARCO, Inc., and Magma Copper Co.) but also *in situ*. Leaching of copper ores has occurred since the 1950s and 1960s, but the use of dump leaching for copper recovery has only become viable during the past decade, with the acceptance of solvent extraction/electrowinning (SX/EW) technology. In this process, oxide ores and low grade sulfide ore (those that cannot be economically milled and recovered by flotation) are placed in lined heaps or unlined dumps, typically with no crushing or grinding. Leaching solution is applied to the surface and collected at the base. Ore can also be leached *in situ*, with leach solution injected into the ore body through wells and recovered in underground workings or through recovery wells. The pregnant solution from these leach operations is collected and conveyed to the SX plant, where the copper is extracted by a proprietary organic chemical dispersed in a kerosene diluent. The copper is then extracted from the organic base with a strong sulfuric acid solution that then becomes the electrolyte for electrowinning. In the electrowinning tankhouse, the copper is plated out of solution onto a cathode suitable for sale. The entire SX/EW process is almost exclusively closed-looped. For low-grade sulfide ores, water is the lixiviant; for oxide ores, sulfuric acid is used to make up leaching solution. To facilitate collection of pregnant solution, dump leach units are typically located within a pit or a natural drainage. Dump leach units (and *in situ* operations) are not always designed to ensure maximum collection of pregnant solution; there are technological limits to containment, but the more important factor is the balance struck between the economics of facility design/construction and the anticipated efficiency of solution recovery. (Another factor, state regulation, is increasingly important: Arizona's new regulations, for example, have led to increased attention on improving solution containment there (EPA, 1994 and 1994a).)

Mineral processing operations generally follow beneficiation and include techniques that often change the chemical make-up of the ore or mineral by chemical attack or digestion, electrolytic refining, and pyrometallurgical/thermal processes. In contrast to extraction and beneficiation wastes, processing operations generate waste streams that generally bear little or no resemblance to the materials that entered the operation.

When mineral processing operations are co-located with extraction and beneficiation operations, commingling of extraction and/or beneficiation and mineral processing wastes (both Bevill and non-Bevill) may occur. Most often, the volume of processing waste is very small compared with the total waste quantity managed on-site (e.g., co-disposing a few thousand tons per year of wastewater treatment sludge with millions of tons of mill tailings). In these cases, management of the mixed waste streams usually occurs in a land disposal unit, such as a tailings pond or other surface impoundment, or, in some industry sectors, a gypsum stack.

Environmental Performance

Mining operations can be and have been sources of widespread environmental impacts, with more than 60 sites on the National Priorities List. During the past 20 years, however, there has been significant improvement in environmental performance at many hardrock mining operations. This is due to many factors:

- Increasing environmental awareness and commitment to environmental protection by many mining companies.
- Better techniques to predict and detect potential environmental effects before damage occurs.
- Continually developing technologies to prevent, mitigate, or remediate environmental impacts.
- Broader state and federal regulatory requirements, including post-mining liability.

Many of the largest mining companies have set up extensive environmental programs. They have begun to incorporate environmental concerns into all phases of mining operations, from exploration to mining planning, through development, operations, closure and reclamation. At some mines, management performance standards now include environmental accomplishments. Other mining companies have set up comprehensive environmental auditing programs. Therefore, environmental costs are now being characterized during the earliest stages of mine planning as part of the economic evaluation of recovering target minerals (EPA, 1994).

The most significant environmental threats posed by mine sites are often complex and highly dependent on site-specific factors. Acid generation potential and water balances, for example, can be very difficult to predict, but also can be very difficult, and expensive, to deal with once problems occur. Poor understanding of water balances, or site hydrology, can contribute to making uninformed decisions about control technologies, and that in turn can result in environmental problems. During the past decade, predictive tools have been greatly improved; this reduces uncertainty and provides more reliable information to develop and carry out mitigation measures. Uncertainty does remain, though, and unanticipated environmental impacts continue to occur at some sites, which emphasizes the need for continued development and refinement of site characterization and mine planning tools (EPA, 1994 and 1994k).

Along with better predictive tools, technologies also continue to be developed to reduce potential environmental threats and address impacts where they do occur. Mining companies have learned to build better, more efficient, and more environmentally safe operations. Advances in liner and other containment systems, piping and spill control, and reclamation techniques are all examples of such improvements. It is important to recognize that the economic costs of environmental controls are a significant element, as is the concentration of the target mineral in the ore body, in the planning and economic evaluation of a site for mine development and operation. Environmental controls must be affordable, cost-effective, and meet certain standards. Where there are potential or actual releases to the environment, treatment and remedial technologies also continue to evolve. For example, nearly 20 years ago, the Homestake Mining Company developed an innovative biotreatment technology for cyanide destruction at the company's gold mine in Lead, South Dakota. Other biotechnologies are being started and improved for cyanide heap leach detoxification and acid drainage control, among other environmental applications. Information management and process controls are also improving environmental performance at many mine and mill sites. By better classifying ore grades and by improving mineral recovery from ore, mines and mills can improve productivity and thus generate somewhat less waste rock or tailings for every pound of metal recovered. (Better classification and recovery, however, have finite limits imposed by the absolute amount of the valuable mineral in the ore and the technologies that are available for recovery.) Because of the high waste-to-product ratios and the volume of wastes generated, however, any improvement in recovery can reduce wastes by substantial amounts (but generally only by small proportions) (EPA, 1994 through 1994k).

Historic mining operations were often unregulated, resulting in extensive uncontrolled environmental releases. In recent decades, particularly since the early 1970s, state and federal agencies have established broad regulatory requirements that generally address all phases of mine operations. During mine planning, operators may be required to complete baseline studies and assess the potential effects of and risks associated with proposed operations. Mine units frequently have to meet specific design standards (liner requirements, stability standards, overflow protection, etc.). Environmental statutes and regulations, such as the Clean Water Act, Clean Air Act and corresponding state requirements, are intended to address environmental releases. Bonding requirements are imposed to ensure that reclamation will be successfully completed. In some states, bonding also serves to protect against environmental problems.

4. MINING AND THE ECONOMY

All non-fuel mineral beneficiation and extraction activities accounted for approximately 0.23% of GNP (Commerce, 1995a) and 0.85% of total employment (Commerce, 1995c) at the national level in 1993. In contrast, the manufacturing industries accounted for 17.63% of GNP (Commerce, 1995a) and 19.2% of total employment (Commerce, 1995c) during the same year. The apparently small portion of the national economy attributed to mining can be traced to several factors: 1) the national economy of the United States is the largest, and most diverse, in the world; 2) improvements in productivity, technology, and mechanization have reduced the need for a large workforce; and 3) the mining sector of the economy has not grown at the same rate as other major sectors of the economy (U.S. Department of Commerce, 1995a).

Although basic non-fuel metal mining occupies a statistically small position in the overall national economy, the mining sector provides basic raw materials for major sectors of the U.S. economy, and thus is more important then the mere numbers suggest. Copper is essential to the electronics and construction industries. Iron ore provides the base material for the steel, automotive, and transportation industries. Molybdenum is used in steel production, machinery, electrical and chemical manufacturing. Potash and phosphate rock are used in fertilizers and chemical manufacturing. Gold, while primarily used in jewelry and the decorative arts, is also used in the electronics industry and dentistry. These minerals are essential to the operation of a modern, industrialized economy. Without a domestic iron ore industry for example, the unit cost to produce automobiles in the United States would be significantly different. Copper, molybdenum, phosphate rock, gold, silver, lead, and zinc play similar roles. The amount of raw materials produced by the U.S. mining industry has provided and will continue to provide raw materials necessary to drive the diverse U.S. economy.

Other important contributions of the minerals industry to the national economy are its value as a producer of exports, and in reducing industrial dependence on certain minerals that would otherwise be imported. For example, in 1994 the United States exported 8% of the lead and 75% of the molybdenum it produced. Conversely, the United States imported 22% of the iron ore it consumed in 1994.

While mining is a small part of the national economy, the importance of mining to state economies varies widely (See Table 6). Of the twelve states producing significant amounts of minerals, there exists a large difference in the percentage of GSP (gross state product) contributed by mining. Generally, states with large, diverse economies (Florida, Missouri) reflect the same trend as is evidenced at the national level: mining is responsible for a very small percentage of GSP. This is even true in Arizona, which is ranked first in terms of dollar value of copper produced, yet whose mining sector accounts for "only" 2.32% of GSP. However, in states with smaller, less diverse economies, mining has a much greater role in the state economy. This is notable in Montana and New Mexico, where mining accounts for 7.39% and 9.38% of GSP, respectively (U.S. Department of Commerce, 1995b). Mining at the state level is similarly important to overall employment. As shown in Table 7, the percentage of state

Table 6. Percentage of GSP Derived from Mining (1992)

State	% GSP
Arizona	2.32
Florida	0.31
Minnesota	0.86
Missouri	0.40
Michigan	0.61
Montana	7.39
Nevada	8.58
New Mexico	9.38
South Carolina	0.25
South Dakota	2.00
Utah	5.15
Wisconsin	0.16

employment in the mining sector is small in the five states that are the major producers of their respective commodities.

Table 7. Economic Status of Mining in Major Producing States (1991)

Leading State	Commodity	Value of Commodity ($)	# of Employees	% State Employment	% State GSP
Nevada	Gold	2.1 billion	11,730	1.86	8.58
Arizona	Copper	2.7 billion	11,800	0.74	2.32
Minnesota	Iron	1.22 billion	6,200	0.27	0.86
Florida	Phosphate Rock	W	W	-	0.31
Missouri	Lead	240 million	4,700	0.18	0.40

Note:
W Data withheld by Bureau of Mines to protect proprietary sources

Sources:
U.S. Department of the Interior, Bureau of Mines. 1993. *State Mineral Commodity Summaries, 1993*.
U.S. Department of Commerce. 1993. *Statistical Abstract of the United States.*

On average, the hardrock mining industry is a viable industry. However, some firms and individual mines, particularly small ones, have financial difficulties. Assessing the financial health of individual commodities is difficult because many firms produce various commodities from various countries. Reports by Standard and Poor's, Moody's and the Value Line assess the finances for the mining companies, which includes non-American holdings. In addition, publicly available financial statements for companies are consolidated, and include the assets, liabilities, and operating accounts of the parent company and its subsidiaries. This creates a problem in trying to understand the financial health of the American hardrock mining industry because the consolidated financial statements include financial information from operations outside of the United States. Therefore, it becomes a problem in distinguishing the financial health of the American mining industry from the world's mining industry.

The discussion below covers the major industry sectors, as reported by Standard & Poor's, Moody's, and the Value Line. Individual commodities not discussed indicates that Standard & Poor's or Moody's did not compile information. Note that the latest financial information reported by Standard & Poor's, Moody's, and the Value Line includes information ending before the economic recovery of the mid-1990s. It should also be noted that the industry's, and individual companies', financial health can be quite volatile over relatively short periods of time, so the discussion that follows is necessarily only a snapshot in time.

Copper. Three financially viable producers dominate the copper mining industry (ASARCO Incorporated, Cyprus Amax Mining Company, and Phelps Dodge). However, other firms are not as financially healthy. From 1989 to 1992, the copper mining industry was characterized by decreasing operating revenues, net income (including some companies with negative net income), asset-use efficiency, average share prices, and earnings per share. Short-term and long-term liabilities have increased for some companies but are stable. Overall the industry is financially secure.

Lead and Zinc. For purposes of its analysis, Standard & Poor's combined the lead and zinc industries. Leading lead producers include The Doe Run Company, ASARCO, and Cominco, while leading zinc producers include Cominco, Doe Run, Jersey Miniere Zinc, and the Green Creek mine (Kennecott, Hecla, and others). From 1988 to 1991, decreasing operating revenues, net income (including some companies with negative net income), asset-use efficiency, average share prices, and earnings per share characterized the lead and zinc mining industry. The industry began a modest improvement in 1992. Short-term and long-term liabilities have remained constant, but decreasing sales has reduced the industry's ability to meet short-term and long-term obligations. Companies focusing on the lead and zinc industry may be problematic.

Gold. The gold mining industry is dominated by a few firms (Barrick Gold Corporation, Echo Bay Mines Limited, Homestake Mining, Lac Minerals Limited, and Newmont Mining Corporation) that are gaining an increasing portion of the market share. None of these firms have a problem meeting either short- or long-term debt. Decreasing operating revenues, net income and increasing liability characterize smaller firms. In the gold mining industry, the major producing companies are financially strong, although other firms within the industry are not as healthy and some have a problem meeting short-term debt.

Silver. Many companies that produce gold also produce silver. Therefore, much said about gold can also be repeated for silver. However, Standard & Poor's classifies a few firms as primarily silver producers (Coeur d'Alene Mines Corporation, Hecla Mining Corporation, and Sunshine Mining Company). Net income for silver producers has continued to decline with the three major silver producers having negative net income during 1991 and 1992. However, the companies do not have liquidity problems. Based on current ratios (current assets divided by current liabilities), the three companies have had consistently large cash reserves.

Miscellaneous sectors. In the metals-miscellaneous category, Standard & Poor's used financial data from several selected companies that mine diverse commodities. On average, for the companies in the miscellaneous category sales, operating income, profit margin, cash flow, and earnings have all decreased. All of the indicators started to decrease in 1988 and continued until 1992. However, based on measures of liquidity for selected companies there does not appear to be a problem meeting short- and long-term liabilities.

Capital Expenditures for Pollution Abatement. The U.S. Bureau of the Census does not separate capital expenditures for pollution from companies identified by SIC codes 10, 11, 12, or 14, but reports them together (those SIC codes include metal mining, industrial minerals mining, and coal mining). In 1991, capital expenditures for pollution abatement equipment was a combined $273.6 million for these four major groups. This included expenditures of $117.5 million for air pollution control, $119.6 million for water pollution control, and $38.5 million for solid waste control (U.S. Department of Commerce, 1993).

5. INACTIVE AND ABANDONED MINES

The number of inactive and abandoned mines in the United States is simply not known. (Although "inactive and abandoned mines," or IAMs, has become a commonly used term, the mines so categorized may be better described as abandoned mines; most mines that are temporarily inactive are still considered "active" by state and federal regulators.) Many federal agencies and others have made estimates of the number of mines, with little consistency and unknown accuracy. There are several areas of agreement among most sources and commentators. First, nearly all agree that the total number of abandoned mines is very large. In addition, there is some agreement that only a minority cause environmental damages--the size of the minority is uncertain, however. Also, many have noted that some mines pose a threat to safety but otherwise pose little or no risk to human health or the environment. Finally, there is also some agreement that the costs of remediation dwarfs available resources, at whatever level.

Major areas of disagreement include the extent to which resources should be devoted to detailed inventories instead of remediation (the ultimate issue is how sites should be ranked), what the cleanup goals should be, and who should be the responsible party (e.g., federal or private land owners or prior claimants/lessees). If additional resources were made available for remediation, the major issue would likely become establishing priorities among sites (Frieders and Raney, 1994).

6. TRENDS

Commodity prices are generally set or at least strongly influenced by the global economy. In addition, there are alternative sources for every commodity mined in the United States, many at lower or marginally higher costs. Thus, increases in production costs in the United States compared with other sources could reduce U.S. production of any commodity.

Future trends in the United States mining industry are almost entirely dependent on various aspects of the domestic and world economies. As such, they are extremely difficult to predict with any degree of certainty. The following are observations (taken largely from Bureau of Mines, 1992a, 1992b, 1993, and 1995) on trends that are likely to occur or that have been predicted.

To some extent, changes in the environmental requirements can affect future trends in the domestic mining industry that are applicable to mining operations. Industry reports (including annual reports and other filings) and Bureau of Mines commentaries nearly always note the uncertainty of future environmental requirements and the impacts those requirements may have on the cost of production. The most commonly cited areas of uncertainty are possible requirements under a RCRA program and possible liability under Superfund. The actual effects of existing regulations (including the many new state requirements), not to mention possible future effects, have not been well assessed.

Gold. Contrary to prices of most metals and other commodities (e.g., copper), gold prices increase in uncertain times. No major economic expansions or retractions are being predicted, so gold production worldwide is likely to hold steady or increase slowly in coming years. Prices should do the same, although increased production from the former Soviet Union could drive prices down somewhat. Unless gold prices increase dramatically, however, U.S. production is likely to decline over time as higher grade deposits are mined out in the contiguous states. Many gold mines that opened in the late 1970s and early 1980s have reached or are nearing the end of their active lives. Thus, unprecedented numbers of mines are (or will be) closing and being reclaimed under “modern” environmental requirements. In addition, future production will come increasingly from lower-grade ores (which will increase waste generation, even as production declines) and ores with higher sulfide content.

Copper. Copper prices and production are very sensitive to global and domestic economic health. Expansions trigger increases in demand and prices, which drive production upward. Increasingly, U.S. mines are leaching copper from lower-grade ores, which significantly increases the waste-per-product ratio. This trend will likely continue, as several major U.S. copper operations have announced major expansions of SX/EW production. State reclamation requirements have only recently been developed and imposed on operations in Arizona and New Mexico, where most copper production occurs, and the impacts of those requirements are not clear.

Lead. Although domestic demand for lead grew an average of 4 percent per year from 1985 to 1989, the Bureau of Mines predicts that the growth in domestic lead demand will range from 0.5 percent to 1.5 percent per year during the 1990s. The availability of scrap lead will influence production increases and decreases in the U.S. secondary industry (Jordan, 1994). The most probable world growth in lead use until the end of the century is forecast to average about 1.5 percent per year. In recent years, the United States has increasingly relied on secondary sources (e.g., scrap batteries), and concern over lead exposure has reduced lead consumption.

Phosphate Rock. World production and consumption have declined steadily since 1989. After 1993, a modest increase was forecast. The long-term growth in phosphate rock production is forecast to average about 1.3 percent annually beginning in 1997.

Iron Ore. The domestic iron ore industry is entirely dependent on the steel industry for sales (molybdenum also is used primarily in the steel industry, and molybdenum trends should follow iron). Dependence is not expected to change in the near future. For the long-term there is little expected growth in the domestic steel industry or countries with highly developed economies. In contrast to the United States, the demand for iron ore is expected to increase, especially in Asia. The increase in iron ore consumption in Asia is expected to benefit Australia rather than the United States

Uranium. Uranium mines within the United States produced 522 metric tons (1.4 million pounds) of U_3O_8 equivalent in 1992. Production figures from 1992 showed a drop of more than 70 percent from 1991 levels and the lowest level of production since 1951. Uranium prices and production are down. In 1992, the average price per pound of uranium oxide equivalent was $8.70, down from an average of $13.66 in 1991 (U.S. Department of Energy, 1993). Uranium requirements in the next two decades are forecast to increase at less than 1 percent per year. Decreases are possible in the near term, as premature shutdowns of existing reactors balance the few new additions. Development of new projects without most or all of the production from the new projects being committed will not occur. In addition, future uranium supplies for nuclear power will contain 15 percent converted weapons material by the year 2000 (Pool, 1994).

Platinum. Platinum sales are dependent largely upon the automobile industry, since platinum is used in catalytic converters. The automobile market is expected to continue growing until 1997 and then to slow (Federal Reserve, 1994).

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