EPA/530//R-95/043
NTIS/PB96/109/103

TECHNICAL DOCUMENT

BACKGROUND FOR NEPA REVIEWERS: NON-COAL MINING OPERATIONS

December 1994

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Washington, DC 20460

Disclaimer and Acknowledgements

This document was prepared by the U.S. Environmental Protection Agency (EPA). The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the EPA.

This Technical Document consists of nine sections. The first is EPA's overview of mining and the statutory and regulatory background. That is followed by a description of mining activities and their potential environmental impacts. The remaining sections cover specific environmental concerns, environmental monitoring, and pollution prevention. Also provided are a list of contacts, glossary, and references. This report was distributed for review to the U.S. Department of the Interior's Bureau of Mines, Bureau of Land Management, and National Park Service; the U.S. Department of Agriculture's Forest Service; Western Governors Association; and other industry and public interest groups.

The use of the terms "extraction," "beneficiation," and "mineral processing" is not intended to classify any waste stream for the purposes of regulatory interpretation or application. Rather, these terms are used in the context of common industry terminology.

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CHAPTER I

INTRODUCTION

The primary purpose of this document is to assist Federal and state officials in providing scoping comments on National Environmental Policy Act (NEPA) documents for non-coal mining activities proposed on Federal lands. Pursuant to NEPA and Section 309 of the Clean Air Act, EPA reviews and comments on environmental impact statements (EISs) prepared for proposed major Federal agency actions significantly affecting the quality of the human environment. This document is constructed to assist the Federal or State reviewer in considering those issues most appropriate to a specific type of mining operation in the development of NEPA/Section 309 comments.

This document is not intended to be all-inclusive. Rather, it focusses on EPA's major concerns with surface water and groundwater, air, and sensitive receptors. This document does not restate traditional NEPA concerns about impacts on floodplains, endangered species, and wetlands since they may occur at any development. Further, the document does not discuss human health risks associated with mining practices, since such risks are site-specific. The document is intended to address all major non-coal mining sectors, including gold and silver, phosphate, and base metals (lead, zinc, copper, tin, and mercury). In addition, key terms are defined in both a technical and regulatory context. For example, the term “beneficiation” has a codified regulatory definition which differs from the definition used in the industry.

The document is organized to provide a general description of site operations, potential environmental impacts, possible prevention/mitigation measures, and the types of questions that should be asked in reviewing a proposed mining operation. Mines and mining operations are designed and operated to account for very site-specific conditions. Therefore, site-specific environmental consequences may result. Thus, the reviewer may have to conduct additional analyses to understand projected impacts more completely.

OVERVIEW OF MINING

Mining operations consist of excavation (extraction in pits, underground mine workings) to remove ore; beneficiation units, such as mills, for upgrading or concentrating ore; and processing facilities for further purification of the metal from the concentrate. Not all of these activities are necessarily conducted at every mine site.

Generally, mines have extraction units that are pits or underground workings, and beneficiation units that are used to crush and size ore and concentrate or separate the valuable minerals from the less valuable material. Mining operations may also maintain processing units on-site, such as smelters and/or refineries that are used to refine or process the mineral into the desired mineral product. In addition, mining sites maintain units to manage wastes generated during their operations. Mining operations generate extremely large quantities of wastes. Overburden and waste rock are the non-liquid wastes generated in largest volumes by extraction activities; tailings and spent ore are generated by beneficiation; and slag is generated through processing.

Surface and underground mining are the two most common types of mining conducted; however, there are two other types of mining, placer and *in situ*. Surface mining methods most commonly employed for the extraction of metals are known as “open-pit” and “open-cut.” Placer mining (including dredging) is used to mine and concentrate surficial sands and gravels. Underground mining techniques use adits and shafts for access and a variety of mining methods. Although surface and underground mines usually operate independently, underground techniques may be used before or after surface methods are employed. *In situ* mining involves the use of solvents (lixiviants) such as water, acids, or alkalies that are injected into an undisturbed ore body to leach and remove the valuable minerals. Major wastes generated by extraction include waste rock and mine water (if it is discharged).

Beneficiation procedures are used to increase the percentage of the desired mineral in the concentrate by separating the metal-bearing minerals from the non-valuable gangue (tailings). The separation is based on one or more differences between the mineral and the rest of the mined material, such as density or chemical nature. Wastes generated from beneficiation operations include tailings, spent lixiviant, excess process water, and spent ore (a form of tailings produced by leaching). Tailings ponds or piles are created as disposal sites for tailings. Spent ore is often left in piles and spent lixiviant may be recycled or neutralized and land-applied on-site.

Mineral processing of ores may also be conducted at the mine site (or at off-site locations). Processing operations often follow beneficiation operations and include techniques that change the chemical makeup of the ore or mineral, such as chemical digestion, electrolytic refining, and pyrometallurgical/thermal processes (roasting or smelting) in order to produce actual metal. Unlike extraction and beneficiation, ore processing generally produces wastes that bear little or no resemblance to the materials that enter the operation.

STATUTORY AND REGULATORY BACKGROUND

Mining operations are subject to a wide range of Federal, state, and local requirements. Many of these require permits before the mining operations commence, while some require approvals or consultations, mandate the submission of various reports, and/or establish specific prohibitions or performance-based standards. The following sections describe the purposes and broad goals of major Federal statutes. The discussion for each statute also provides an overview of the requirements and programs that are implemented by the respective implementing agencies.

Clean Water Act

The objective of the Clean Water Act (CWA)(33 U.S.C. §§ 1251-1376) is to “restore and maintain the chemical, physical, and biological integrity of the Nation's waters” (§101(a)). This is to be accomplished through the control of both point and nonpoint sources of pollution (§101(a)(7)). A number of interrelated provisions of the Act establish the structure by which the goals of the Act are to be achieved. Within this overall structure, a variety of Federal and State programs are implemented to meet the Act's requirements.

Under §303, states are responsible for establishing water quality standards for waters under their jurisdictions: these are the beneficial uses that various waters are to support and the numeric (and narrative) criteria that must be achieved to allow these uses to be met. Water quality standards serve as a basis both for identifying waters that do not meet their designated uses and for developing effluent limits in permitted discharges. EPA also establishes nonbinding numeric water quality criteria as guidance; when states fail to adopt sufficient water quality standards, EPA may do so.

Under §402 of the Act, all point source discharges of pollutants to navigable waters of the United States must be permitted under the National Pollutant Discharge Elimination System (NPDES). The term “point source” means "any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged” (CWA §502(14)). Effluent limits in NPDES permits may be either technology- or water quality-based. For various categories of industries, EPA establishes National technology-based effluent limitation guidelines pursuant to §§301, 306, and 307. More stringent water quality-based permit limits may be established when technology-based limits do not result in achievement of water quality standards. Additionally, states may establish effluent limits based on a “non-degradation” principle which does not allow for the receiving stream to be degraded from previously existing conditions.

EPA's NPDES regulations (40 CFR 122.21(l)) require prospective dischargers (in states without an approved NPDES program) to submit information to the EPA Region, prior to beginning on-site construction. Review of this information allows EPA to make a determination as to whether the facility is a new source. The Region must then issue a public notice of the determination. If the facility is determined to be a new source, the issuance of the NPDES permit by EPA is subject to NEPA and the applicant and EPA must comply with the environmental review requirements of 40 CFR Part 6 Subpart F.

EPA has established National technology-based effluent limitation guidelines for ore mining and dressing operations (40 CFR Part 440). These include new source performance standards based on the Best Available Demonstrated Technology (BADT), since new plants can install the best and most efficient

EXHIBIT 1-1
EXAMPLES OF DISCHARGES FROM ORE MINING AND DRESSING FACILITIES THAT ARE SUBJECT TO 40 CFR PART 440 OR TO STORM WATER PERMITTING

Runoff/drainage discharges subject to 40 CFR Part 440 effluent limitation guidelines	**Subject to storm water permitting (not subject to 40 CFR Part 440)**
Mine drainage limits	Topsoil piles Haul roads not on active mining area On-site haul roads not constructed of waste rock or spent ore (unless wastewater subject to mine drainage limits is used for dust control) Tailings dams/dikes when not constructed of waste rock/tailings [1] Concentration/mill building/site (if discharge is storm water only, with no contact with piles) Reclaimed areas released from reclamation bonds prior to 12/17/90 Partially/inadequately reclaimed areas or areas not released from reclamation bond Most ancillary areas (e.g., chemical and explosives storage, power plant, equipment/truck maintenance and wash areas, etc.)
Land application area [1] Crusher area [1] Spent ore piles [1], surge piles, ore stockpiles, waste rock/overburden piles Pumped and unpumped drainage and mine water from pits/underground mines Seeps/French drains [1] On-site haul roads, if constructed of waste rock or spent ore or if wastewater subject to mine drainage limits is used for dust control Tailings dams/dikes when constructed of waste rock/tailings [1] Unreclaimed disturbed areas	
Mill discharges limits (including zero discharge limits)	
Land application area [1] Crusher area [1] Spent ore piles [1], surge piles, waste rock/overburden piles Seeps/French drains [1] Tailings impoundment/pile Heap leach runoff/seepage Pregnant, barren, overflow, and polishing ponds Product storage areas (e.g., concentrate pile)	

NOTE:

[1] Point source discharges from these areas are subject to 40 CFR Part 440 effluent limitation guidelines for (a) mills if process fluids are present or (b) mine drainage if process fluids are not.

production processes and wastewater treatment technologies. In general, the effluent limitations address mine drainage and mill discharges. Exhibit 1-1 provides examples of point source discharges that are subject to mine drainage and mill discharge limits (and examples of those that are subject to storm water permitting).

§402(p)(2)(B) (added by the Water Quality Act of 1987) required that point source discharges of storm water associated with industrial activity be permitted by October 1, 1992. Pursuant to this requirement, EPA's storm water program requires that all point source discharges of storm water associated with industrial activity, including storm water discharges from mining activity, be permitted under the NPDES program. "Storm water" is defined at 40 CFR 122.26(b)(13) as "storm water runoff, snow melt runoff, and surface runoff and drainage." "Storm water associated with industrial activity" is defined at §122.26(b)(14) as "the discharge from any conveyance which is used for collecting and conveying storm water and which is directly related to manufacturing, processing, or raw materials storage areas at an industrial plant . . . ." It also includes discharges from "areas where industrial activity has taken place in the past and significant materials remain and are exposed to storm water." There are no New Source Performance Standards for storm water discharges, so the issuance of an NPDES permit for storm water discharges (or the coverage by an existing permit of a new or previously unpermitted discharge) may not trigger NEPA.

§404 of the Clean Water Act addresses the placement of dredged or fill material into waters of the U.S. and has become the principal tool in the preservation of wetland ecosystems. "Jurisdictional wetlands" are those subject to regulation under §404. Jurisdictional wetlands are those that meet the criteria defined in the 1987 Corps of Engineers Wetlands Delineation Manual (USACE, 1987). Regulatory authority for §404 is divided between the Army Corps of Engineers (Corps) and EPA. §404(a) establishes the requirement for the Corps to issue permits for discharges of dredged or fill materials into waters of the United States at specific disposal sites. Disposal sites are to be specified for each permit using the §404(b)(1) guidelines; the guidelines were established by EPA in conjunction with the Corps. Further, §404(c) gives EPA the authority to veto any of the permits issued by the Corps under §404. In practice, EPA rarely exercises its veto power as it typically reviews and provides comments on §404 permits prior to their issuance, and any disputes are resolved at that time.

Clean Air Act

The Clean Air Act (CAA) (42 U.S.C. §§7401-7626) requires EPA to develop ambient air quality standards as well as standards for hazardous air pollutants. The Act also imposes strict performance standards applicable to new or modified sources of air pollution, a stringent approval process for new sources of pollution in both attainment and non-attainment areas, and emission controls on motor vehicles.

Under §109, EPA has established national primary and secondary ambient air quality standards for six "criteria" pollutants. These are known as the National Ambient Air Quality Standards (NAAQSs). The NAAQSs set maximum concentrations in ambient air for lead, nitrogen oxides, sulfur dioxide, carbon monoxide, suspended particulate matter of less than 10 microns in diameter, and ozone. States and local authorities have the responsibility for bringing their regions into compliance with NAAQSs or more stringent standards they may adopt. This is accomplished through the development and implementation of State Implementation Plans (SIPs), which are EPA-approved plans that set forth the pollution control requirements applicable to the various sources addressed by each SIP.

Under §111, EPA has promulgated New Source Performance Standards (NSPSs) applicable to metallic mineral-processing plants (40 CFR Part 60, Subpart LL). A processing plant is defined as "any combination of equipment that produces metallic mineral concentrates from ore; metallic mineral processing commences with the mining of the ore." However, all underground processing facilities are exempt from the NSPSs. Also, NSPS particulate emission concentration standards apply only to stack emissions.

In addition to the NSPSs, Prevention of Significant Deterioration (PSD) provisions are intended to ensure that NAAQS are not exceeded in those areas that are in attainment for NAAQSs. Under this program, new sources are subject to extensive study requirements if they will emit (after controls are applied) specified quantities of certain pollutants.

State programs to meet or exceed Federal NAAQSs are generally maintained through permit programs that limit the release of airborne pollutants from industrial and land-disturbing activities. Fugitive dust emissions from mining activities may be regulated through these permit programs (usually by requiring dust suppression management activities).

As indicated above, only six criteria pollutants are currently regulated by NAAQSs. Several other pollutants are regulated under National Emission Standards for Hazardous Air Pollutants (NESHAPs). NESHAPs address health concerns that are considered too localized to be included under the scope of NAAQSs. Prior to the passage of the Clean Air Act Amendments of 1990, EPA had promulgated NESHAPs for seven pollutants: arsenic, asbestos, benzene, beryllium, mercury, vinyl chloride, and radionuclides (40 CFR Part 61).

The CAA Amendments of 1990 substantially revised the existing statutory provisions of the CAA. The Amendments require that states develop air emission permit programs for major sources (these will supplement SIPs) and dramatically expand the air toxics (i.e., NESHAPs) program to address 189 specific compounds. Under the Amendments, Congress required EPA to establish stringent, technology-based standards for a variety of hazardous air pollutants, including cyanide compounds. In November 1993, EPA published a list of source categories and a schedule for setting standards for the selected sources. Among the mining-related industry groups that have been identified as sources of hazardous air pollutants are the ferrous and non-ferrous metals processing industries, and the minerals products processing industry (58 FR 63952; 12/3/93). Under the amended air toxics program, if a source emits more than 10 tons per year of a single hazardous air pollutant or more than 25 tons per year of a combination of hazardous air pollutants, the source is considered a "major source." Major sources are required to use the Maximum Available Control Technology (MACT) to control the release of the pollutants (CAA §112). The CAA Amendments also intensify the requirements applicable to nonattainment areas.

Resource Conservation and Recovery Act

The Solid Waste Disposal Act was amended in 1976 with the passage of the Resource Conservation and Recovery Act (RCRA)(42 U.S.C. §§6901-6992k). Under Subtitle C of RCRA, EPA has established requirements for managing hazardous wastes from their generation through storage, transportation, treatment, and ultimate disposal. Hazardous wastes include specific wastes that are listed as such under 40 CFR §261 Subpart D as well as other wastes that exhibit one or more EPA-defined "characteristics," i.e., reactivity, corrosivity, ignitability, and toxicity. Other solid wastes (which can be solid, liquid, or gaseous) that are not hazardous wastes are subject to Subtitle D, under which EPA establishes criteria for State management programs, approves State programs, and can provide funding for State implementation. EPA has promulgated specific criteria for municipal solid wastes and more general criteria for all nonhazardous solid wastes.

The scope of RCRA as it applies to mining waste was amended in 1980 when Congress passed the Bevill Amendment, RCRA §3001(b)(3)(A). The Bevill Amendment states that "solid waste from the extraction, beneficiation, and processing of ores and minerals" is excluded from the definition of hazardous waste under Subtitle C of RCRA (40 CFR §261.4(b)(7)). The exemption was conditional upon EPA's completion of studies required by RCRA §8002(f) and (p) on the environmental and health consequences of the disposal and use of these wastes. EPA then conducted separate studies of extraction and beneficiation wastes and mineral processing wastes (including smelting and refining wastes). EPA submitted the results of the first study in the 1985 *Report to Congress: Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden From Uranium Mining, and Oil Shale* (EPA, 1985b). In July 1986, EPA made a regulatory determination that regulation of extraction and beneficiation wastes as hazardous wastes under Subtitle C was not warranted (51 *FR* 24496; July 3, 1986).

EPA reported its findings on mineral processing wastes from the studies required by the Bevill Amendment in the 1990 *Report to Congress: Special Wastes From Mineral Processing* (EPA, 1990). This report covered 20 specific mineral processing wastes. In June 1991, EPA issued a regulatory determination (56 *FR* 27300; June 13, 1990) stating that regulation of these 20 mineral processing wastes as hazardous wastes under RCRA Subtitle C is inappropriate or infeasible. Eighteen of the wastes are subject to applicable State requirements. The remaining two wastes (phosphogypsum and phosphoric acid process waste water) are currently being evaluated by EPA. Five additional types of wastes are listed as hazardous wastes and must be managed as such; other than these and the 20 wastes exempted in 1991, mineral processing wastes are subject to regulation as hazardous waste if they exhibit one or more hazardous waste characteristics.

EPA interprets the exclusion from hazardous waste regulation to encompass *only those wastes that are uniquely associated with the extraction and beneficiation of ores and minerals*. Thus, the exclusion does not apply to wastes that may be generated at a mine site but that are not uniquely associated with mining. For example, waste solvents are listed as a hazardous waste under 40 CFR §261.31 (Hazardous Wastes from Nonspecific Sources); they are generated at mining sites as a result of cleaning metals parts. Because this activity (and this waste) is not uniquely associated with extraction and beneficiation operations, such solvents must be managed as any other hazardous wastes, subject to the Federal requirements in 40 CFR Parts 260 through 271, or State requirements if the State is authorized to implement the RCRA Subtitle C program. In practice, most mine sites generate relatively modest quantities of hazardous wastes.

Endangered Species Act

The Endangered Species Act (ESA) (16 U.S.C. §§1531-1544) provides a means whereby ecosystems supporting threatened or endangered species may be conserved as well as a program for the conservation of such species. Section 7 of the ESA requires Federal agencies to ensure that all Federally associated activities within the United States do not have adverse impacts on the continued existence of threatened or endangered species or on critical habitat that are important in conserving those species. Agencies undertaking a Federal action must consult with the U.S. Fish and Wildlife Service (USFWS), which maintains current lists of species that have been designated as threatened or endangered, to determine the potential impacts a project may have on protected species. The National Marine Fisheries Service undertakes the consultation function for marine and anadromous fish species while the USFWS is responsible for terrestrial (and avian), wetland and fresh-water species.

The USFWS has established a system of informal and formal consultation procedures; these must be undertaken as appropriate in preparing an EA or EIS. Many states also have programs to identify and protect threatened or endangered species other than Federally listed species. An EIS must be prepared if "any major part of a new source will have significant adverse effect on the habitat" of a Federally or state-listed threatened or endangered species (40 CFR 6.605(3)). If a Federally listed threatened or endangered species may be located within the project area and/or may be affected by the project, a detailed endangered species assessment (Biological Assessment) may be prepared independently or concurrently with the EIS and included as an appendix. States may have similar requirements for detailed biological assessments as well.

National Historic Preservation Act

Where mining activities involve a proposed Federal action or Federally assisted undertaking, or require a license from a Federal or independent agency, and such activities affect any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places, the agency or licensee must afford the Advisory Council on Historic Preservation a reasonable opportunity to comment with regard to the undertaking. Such agencies or licensees are also obligated to consult with state and Native American Historic Preservation Officers responsible for implementing approved state programs.

As provided for in 40 CFR 6.605(b)(4), issuance of a new source NPDES permit that will have "significant direct and adverse effect on a property listed in or eligible for listing in the National Register of Historic Places" triggers the preparation of an EIS. Many proposed mining operations are located in areas where mining has occurred in the past. Particularly in the west, states and localities are viewing the artifacts of past mining (e.g., headframes, mill buildings, even waste rock piles) as valuable evidence of their heritage. Since modern mining operations can damage remnants of historic operations, care must be taken to identify valuable cultural resources and mitigate unavoidable impacts.

Mining Law of 1872

The Mining Law of 1872 (30 U.S.C. §§22-54) establishes the conditions under which citizens of the United States can explore and purchase mineral deposits and occupy and purchase the lands on which such claims are located. The basic provision of the law provides that:

> Except as otherwise provided, all valuable mineral deposits in lands belonging to the U.S. . . . shall be free and open to exploration and purchase, and the lands in which they are found to occupation and purchase, by citizens of the U.S. . . . under regulations prescribed by law, and according to the local customs or rules of miners in the several mining districts, so far as the same are applicable and not inconsistent with the laws of the U.S.

The Mining Law establishes the basic standards for the location, recording, and patenting of mining claims. In general, persons are authorized to enter Federal lands and establish or locate a claim to a valuable mineral deposit (originally, nearly all minerals but now a much more restricted number, as described below). Once a claim has been properly located (and, since 1976, recorded with BLM), the claimant gains a possessory right to the land for purposes of mineral development and thereafter retains the claim if small amounts of development work are done or small fees are paid. Upon proving that a valuable mineral deposit has been discovered, claim holders may patent the claim and purchase the land for nominal sums. Except as specifically authorized by law (e.g., certain inholdings), land management agencies have no further jurisdiction over patented lands. Mining claims, whether patented or not, are fully recognized private interests that may be traded or sold. The possessory interest is considered private property subject to Fifth Amendment protection against takings by the United States without just compensation. The standards set in the Mining Law may be supplemented by local law not in conflict with the Mining Law or State law.

Over time, various laws have restricted the minerals that are subject to location under the Mining Law; restrictions were generally not retroactive but were subject to valid existing rights. "Locatable" minerals subject to location of claims under the Mining Law now include most metallic minerals (except uranium) and some nonmetallic minerals. In addition, certain Federal lands have been or may be closed to mineral development, subject to valid existing rights (these include the National Parks and National Monuments, among other lands). In addition, only "public domain" lands are generally open to mineral location under the Mining Law.

Federal Land Policy Management Act

The Federal Land Policy Management Act (FLPMA) (43 U.S.C. §§1701-1782) provides the Bureau of Land Management (BLM) with authority for public land planning and management, and governs such disparate land use activities as range management, rights-of-way and other easements, withdrawals, exchanges, acquisitions, trespass, and many others. FLPMA declares it to be the policy of the United States to retain lands in public ownership (i.e., rather than "disposing" of the lands by transferring ownership to private parties) and to manage them for purposes of multiple use and sustained yield. Under §202, BLM must develop and maintain plans for the use of tracts or areas of the public lands. To the extent feasible, BLM must coordinate its land use planning with other Federal, State, and local agencies. BLM also must provide for compliance with "applicable" pollution control laws (including Federal and State air, water, and noise standards and implementation plans) in the development and revision of land use plans. The overall protective standard is provided in §302(b), under which BLM is to take any necessary action, including regulation, to prevent "unnecessary or undue degradation" of public lands. Subject to this and several more limited exceptions, nothing in FLPMA "shall in any way amend the Mining Law of 1872 or impair the rights of any locators of claims under that Act, including, but not limited to, rights of ingress and egress" (§302(b)).

BLM regulations (43 CFR Group 3800) impose a number of broad requirements upon operations on BLM-managed lands, but contain few specific technical standards. The basic compliance standard is that operations must be conducted so as to prevent unnecessary or undue degradation of the lands or their resources, including environmental resources and the mineral resources themselves. According to 43 CFR §3809.0-5(k), "unnecessary or undue degradation" means surface disturbance greater than what would normally result when an activity is being accomplished by a prudent operator in usual, customary, and proficient operations of similar character and taking into consideration the effects of operations on other resources and land uses, including those resources and uses outside the area of operations. Failure to initiate and complete reasonable mitigation measures, including reclamation of disturbed areas, may constitute unnecessary or undue degradation. Finally, failure to comply with applicable environmental protection statutes and regulations constitutes unnecessary and undue degradation.

BLM's implementing regulations pertaining to development of mining claims include three levels of review:

- **Casual use**—for which no notification or approval is necessary
- **Notice-level**—for cumulative annual disturbances that total less than five acres. Operators must notify BLM officials (and commit to reclamation), but no approval is required. Consultation may be required if access routes are to be constructed.
- **Approval-level**—for disturbances exceeding 5 acres in a calendar year or any disturbance in certain specified areas (wilderness areas, wild and scenic rivers, critical habitat, areas of the California Desert Conservation Area). Operators must obtain BLM approval (within specified timeframes) of a plan of operations for such disturbances.

A plan of operations must describe in detail the site and the proposed operation, including measures that will be taken to prevent undue and unnecessary degradation and to reclaim the site to regulatory standards. Reclamation must include salvaging topsoil for later use, erosion and runoff control, toxic materials isolation and control, reshaping the area, reapplication of topsoil, and revegetation (where reasonably practical). BLM may require operators to furnish bonds (site-specific or blanket) or cash deposits, with the amount left to the responsible official (policy now calls for full reclamation bonding for cyanide and other chemical leaching operations, and a similar policy is anticipated to be issued for potentially acid-generating mines). Following approval of a plan of operation, BLM may monitor the operation to ensure that the approved plan is being followed. Failure to follow approved plans of operations, or to reclaim lands, may result in a notice of noncompliance, which in turn can lead to injunctive relief.

Plans of operations may be modified at BLM's request or at the operator's behest. Significant modifications follow the same review and approval procedures as original plans. Proposed plans of operations (and modifications) are reviewed by BLM "in the context of the requirement to prevent unnecessary and undue degradation and provide for reasonable reclamation" (§3809.1-6(a)).

Upon receipt of a proposed plan of operations (or modification), BLM must conduct an environmental assessment (or supplement). This EA is used to assess the adequacy of proposed mitigation measures and reclamation procedures to prevent unnecessary and undue degradation. The EA then leads to a Finding of No Significant Impact (with or without stipulations) or to the preparation of an EIS and Record of Decision. If the proposed operation is to be issued a new source NPDES permit and is in a State where EPA is the permitting authority, or in other cases where EPA has significant environmental concerns, EPA typically becomes a cooperating agency in the NEPA process. In any event, EPA has the opportunity to review all EISs pursuant to §309 of the Clean Air Act.

National Park System Mining Regulation Act

The National Park System Mining Regulation Act (also known as the Mining in the Parks Act, or MPA) (16 U.S.C. §§1901-1912) reconciles the recreational purpose of the National Park System with mining activities affecting park lands. The Act subjects mining activities within the National Park System to such regulations as deemed necessary by the Secretary of the Interior. It also required that all mining claims within the park system be recorded by September 1977, or become void.

The National Park Service has extensive regulations governing exercise of valid existing mineral rights (36 CFR Part 9 Subpart A). The regulations restrict water use, limit access, and require complete reclamation. They also require that operators obtain an access permit and approval of a plan of operations prior to beginning any activity. A plan of operations requires specific site and operations information, and may require the operator to submit a detailed environmental report. Operators must comply with any applicable Federal, State, and local laws or regulations.

Organic Act; Multiple Use and Sustained Yield Act; National Forest Management Act

The Organic Act of 1897 (16 U.S.C. §§473-482, 551) has governed the Forest Service's activities since the earliest days of National Forest management. The Act delegates broad authority over virtually all forms of use in the National Forest System. It also provides for continued State jurisdiction over National Forest lands. Finally, it declares that forests shall remain open to prospecting, location, and development under applicable laws, and that waters within the boundaries of the National Forests may be used for domestic mining and milling, among other uses.

The Multiple Use and Sustained Yield Act of 1960 (MUSYA) (16 U.S.C. §§528-531) established that the National Forest System is to be managed for outdoor recreation, range, timber, watershed, and fish and wildlife purposes, and that these purposes are supplemental to the purposes for which the National Forests were established as set forth in the Forest Service Organic Legislation (16 U.S.C. §§475, 477, 478, 481, 551). MUSYA provides that the renewable surface resources of the National Forests are to be administered for multiple use and sustained yield of products and services. Nothing in MUSYA is intended to affect the use or administration of the mineral resources of the National Forest lands (16 U.S.C. §528). Section 530 of the MUSYA authorizes the Forest Service to cooperate with State and local governments in managing the National Forests. The National Forest Management Act of 1976 provides the Forest Service with authorities and responsibilities similar to those provided to BLM by

FLPMA. It establishes a planning process for National Forests that in many ways parallels the process established under FLPMA for BLM lands.

Forest Service regulations (36 CFR Part 228) are broad and similar to BLM's in that they impose few specific technical standards. In all cases where the land's surface is to be disturbed, operators must file a notice of intent. For significant disturbances (i.e., where mechanized equipment or explosives are to be used), operators must submit a proposed plan of operations. Forest Service regulations concerning plans of operations and their review and approval, reclamation standards, and environmental review are similar to those described for BLM above. Like BLM's regulations, they require compliance with the Clean Water Act and other environmental statutes and regulations.

Mineral Leasing Act; Mineral Leasing Act for Acquired Lands

The Mineral Leasing Act of 1920 (MLA) (30 U.S.C. §§181-287) and the Mineral Leasing Act for Acquired Lands (1947) (30 U.S.C. §§351-359) create a leasing system for coal, oil, gas, phosphate, and certain other fuel and chemical minerals ("leasable" minerals) on Federal lands. In addition, §402 of Reorganization Plan No. 3 of 1946 (and other authorities) authorizes leases for locatable minerals on certain lands (e.g., some acquired lands, as opposed to public domain lands). Under the leasing system, the government determines which acquired lands will be available for mineral development. The Department of the Interior has promulgated extensive regulations governing various aspects of leases. BLM may issue competitive, noncompetitive, and preference right leases that set the terms, including environmental terms, under which mineral development can take place. Prior to lease issuance, BLM must consult with the appropriate surface managing agency (e.g., the Forest Service), and for acquired lands must have the written consent of the other agency. Regulations require compliance with Federal and State water and air quality standards, and failure to comply with lease terms can result in lease suspension or forfeiture.

CHAPTER II

DESCRIPTION OF MINING ACTIVITIES

INTRODUCTION

This chapter presents a brief technical description of the processes and activities associated with metal and phosphate ore mining as currently practiced in the United States. The chapter has been divided into five sections: (1) ore extraction; (2) beneficiation; (3) mineral processing; (4) ancillary operations; and (5) waste management practices. Since many of the practices for mining various metal ores are similar, this chapter describes general concepts of ore mining and ore beneficiation which apply to one or more of the commodity sectors. Exhibit 2-1

EXHIBIT 2-1
SECTOR-SPECIFIC PROCESSES AND WASTES/MATERIALS

Sector	Mining Type	Beneficiation/Processing	Primary Wastes & Materials
Gold-Silver	• Surface • Underground • *In Situ* (experimental)	• Cyanidation • Elution • Electrowinning/Zinc Precipitation • Milling • Base Metal Flotation • Smelting • Amalgamation (historic)	• Mine Water[1] • Overburden/Waste Rock • Spent Process Solutions • Tailings • Spent Ore
Gold Placer	• Surface	• Gravity Separation Roughing Cleaning Fine Separation • Some Magnetic Separation	• Mine Water[1] • Overburden/Waste Rock • Tailings
Lead-Zinc	• Underground (exclusively)	• Milling • Flotation • Sintering • Smelting	• Mine Water[1] • Overburden/Waste Rock • Tailings • Slag
Copper	• Surface • Underground • *In Situ*	• Milling • Flotation • Smelting • Acid Leaching • SX/EW Recovery • Iron Precipitation/Smelting	• Mine Water[1] • Overburden/Waste Rock • Tailings • Spent Ore • Spent Leach Solutions • Slag
Iron	• Surface (almost exclusively) • Underground	• Milling • Magnetic Separation • Gravity Separation • Flotation • Agglomeration • Blast Furnace	• Mine Water[1] • Overburden/Waste Rock • Tailings • Slag
Uranium	• Surface • In Situ	• Milling • Leaching • Solvent Extraction/Ion Exchange • Precipitation	• Mine Water[1] • Overburden/Waste Rock • Tailings • Spent Leach Solution
Aluminum	• Surface	• Crushing • Washing • Drying • Bayer Process • Electrolytic Reduction	• Mine Water[1] • Overburden/Waste Rock • Mill Wastewater • Red Mud
Molybdenum	• Surface • Underground	• Milling • Flotation • Smelting	• Mine Water[1] • Overburden/Waste Rock • Tailings • Slag
Phosphate	• Surface	• Washing • Sizing • Flotation • Heavy Media Separation • Elemental Phosphorus Furnace • Acid Digestion (Phosphoric Acid Production)	• Overburden • Waste Rock • Tailings • Mill Washwater/Wastewater • Spent Media • Slag • Phosphogypsum

NOTE:
[1] Mine water is a waste if it is discharged to the environment via a point source.

summarizes the principal mining type, beneficiation process, and associated wastes for each major hardrock mining sector.

EXTRACTION

A wide variety of techniques are used to extract minerals from the earth. In general, mining consists of removing ore and associated rock or matrix in bulk form from a deposit and transporting it away from the mined site. In the interests of economic efficiency, the extraction process is designed to remove ore of a predetermined grade or higher, leaving behind lower-grade material and barren rock, if at all practicable. In practice, an ideal separation is not often possible, so that some lower-grade rock is mined and some higher-grade ore is left behind. Although mining processes may be classified according to the numerous techniques that are employed in removing ore, they can be broken down into two broad categories associated with the general setting of a mining operation: (1) surface mining or open-pit processes; and (2) underground mining processes.

Surface Mining

Surface mining techniques are used for most of the major metallic ores in the United States. This is the method of choice when the ore deposit is near the surface, or is of sufficient size to justify removing overburden. At present, this is the most economical way of mining highly disseminated (lower-grade) ores. Surface mining methods typically used for ore extraction are described below.

Open pit mining involves ground excavation and ore removal from the resulting pit. Depending on the thickness of the ore body, it may be removed as a single vertical interval or in successive intervals, or “benches.” In resistant materials, the procedure usually employed involves mining each bench by drilling vertical shot holes from the top of the bench, and then blasting the ore onto the adjacent lower level. The broken ore and waste rock then is loaded into trucks or rail cars for transport to a mill or waste rock dumps. In less resistant materials, the ore may be excavated by scrapers or digging machinery without the use of explosives.

The depth to which an ore body is mined depends on the ore grade, nature of the overburden, and the “stripping ratio.” The stripping ratio is the amount of overburden and waste rock that must be removed for each unit of crude ore mined and varies with the mine site and the ore being mined. Note that, the cut-off grades at a given mine may change with the price of the ore, thus leading to more or less waste rock being disposed as the stripping ratio changes. Waste rock with ore concentrations just below the “cut-off” grade (i.e., the grade at which ore can be recovered economically) may be stockpiled separately from other waste rock. The primary wastes associated with open pit mining include mine water, waste rock, and overburden.

Placer deposits associated with watercourses or beaches (either current or ancient) can be mined by surface open pit methods, but in some cases can be better accessed by dredging. Although there were no known commercial dredges operating in the United States as of the 1990s, the practice, which for hard materials uses a mechanical digging system to break up and excavate the deposit, may be in use elsewhere. The primary wastes associated with placer mining include mine water and tailings (which closely resemble waste rock generated in other sectors).

Underground Mining

Historically, underground mining was the major method used for the extraction of many metal ores, however, it is now much less commonly used in hardrock mining in the United States. There are numerous variations and combinations of underground mining techniques which have been developed in response to specific or unusual characteristics of the ore body. In general, underground mining involves sinking a shaft or “driving a drift” near the ore body to be mined and extending horizontal passages (“levels”) from the main shaft at various depths to the ore. Mine development rock is removed, while sinking shafts, adits, drifts, and cross-cuts, to access and exploit the ore body. From deep mines, broken ore (or “muck”) is removed from the mine either through shaft conveyances or chutes and hoisted in skips (elevators). From shallow mines, ore may be removed by train or conveyor belt. Wastes associated with underground mining include mine water and mine development rock (waste rock).

In situ mining[1] is a method of underground mining that is applicable to certain ores under certain geohydrologic conditions. *In situ* mining involves mining a deposit in place using a lixiviant to leach the desired material from the deposit. When the deposit is not sufficiently permeable, blasting may be used to fracture the ore body. In buried ore bodies, leaching solution is injected through a well into the ore zone. At surface ore bodies, the solution can simply be sprayed over the deposit. Recovery wells (or old underground workings) are used to collect the pregnant solution after it percolates through the ore.

In situ leaching is currently used in the uranium and copper industries. *In situ* techniques have also been used experimentally in the gold industry. Use of *in situ* methods has obvious geochemical restrictions based upon the amenability of the ore minerals to being solubilized and the cost and practicality of solvents, and based on concerns related to groundwater quality. Hydrologic requisites include: (1) the host rock must be permeable to circulating fluids; and (2) the host rock must be overlain and underlain by impermeable formations or rock units that restrict the vertical flow of fluids. Wastes associated with *in situ* mining include spent leaching solutions.

BENEFICIATION

Most ores contain valuable metals disseminated in a matrix of less valuable rock called “gangue” (pronounced gang). The purpose of ore beneficiation is to separate valuable minerals from the gangue yielding a product much higher in content of the valued material. To accomplish this, ore generally must be crushed and/or ground small enough so that each particle is composed predominantly of the mineral to be recovered or of gangue. This separation of the particles on the basis of some difference in physical or chemical properties between the ore mineral and the gangue yields a concentrate high in values, as well as waste (tailings) containing very low concentrations of values.

Many properties are used as the basis for separating valuable minerals from gangue, including: specific gravity, conductivity, magnetic permeability, affinity for certain chemicals, surface tension, solubility, and the tendency to form chemical complexes. Because of their widespread usage throughout the mining industry, descriptions of flotation (i.e., conventional milling) and leaching processes are provided below.

Flotation

Prior to flotation, run-of-mine ores are reduced in particle size by crushing and/or grinding techniques. Crushing is commonly performed sequentially: first with jaw type crushers and, then, with cone crushers and screens which reduce the particles to approximately 3/4 inch. Grinding may then occur in ball or rod mills or in autogenous mills. Grinding is usually performed with the addition of water and the resulting slurry is then pumped to the flotation circuit. Froth flotation is a process in which the addition of chemicals to an ore slurry causes particles of one mineral or group of minerals to adhere preferentially to air bubbles. When air is forced through a slurry of mixed minerals, the rising bubbles carry with them the particles of the mineral(s) to be separated from the matrix. If a foaming agent is added to prevent the bubbles from bursting when they reach the surface, a layer of mineral-laden foam is built up at the surface of the flotation cell which may be removed to recover the mineral (or, in some cases, the gangue). Requirements for success of the operation are small particle size (typically flour-sized or less), use of reagents compatible with the mineral to be recovered, and water conditions in the cell which do not interfere with the attachment of reagents to minerals or to air bubbles.

Although the exact specifications for adequate flotation are highly variable, a complex system of reagents is generally used, including five basic types of compounds: pH conditioners (regulators, modifiers), collectors, frothers, activators, and depressants. Collectors serve to attach ore particles to air bubbles formed in the flotation cell. Frothers stabilize the bubbles to create a foam which may be effectively recovered from the water surface. Activators enhance the attachment of the collectors to specific kinds of particles, while depressants prevent such attachment. Activators are frequently used to allow flotation of particular minerals that have been depressed at an earlier stage of the milling process. In almost all cases, use of each reagent in the mill is generally less than 0.5 kg (approximately 1 lb.) per ton of ore

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[1] Note that under RCRA, in situ mining is actually included in the definition of beneficiation operations, see Chapter VIII-Glossary.

processed; however, at large-capacity mills, the total reagent usage can be high, since thousands of tons of ore per day may be beneficiated.

Sulfide minerals are all readily amenable to flotation using similar reagents in small doses, although reagent requirements and ease of flotation vary throughout the mining industry class. Sulfide minerals of copper, lead, zinc, molybdenum, silver, nickel, and cobalt are commonly recovered by flotation. In addition to sulfides, other types of minerals may be recovered by flotation (e.g., oxidized ores of iron, copper, manganese, the rare earths, tungsten, titanium, phosphate, columbium, and tantalum). The primary wastestream associated with flotation/conventional milling is tailings.

Leaching

Leaching is the process of extracting a soluble metallic compound from an ore by selectively dissolving it in a suitable solvent such as water, sulfuric or hydrochloric acid, or cyanide solution. The desired metal is then removed from the "pregnant" leach solution by chemical precipitation or another chemical or electrochemical process. Leaching methods include "heap," "dump," and "tank" operations. Heap leaching is widely used in the gold industry, and dump leaching in the copper industry; leaching operations in these two sectors are discussed in detail below.

Cyanidation

The predominant methods used in the U.S. to beneficiate gold ore involve cyanidation. This technique uses solutions of sodium cyanide or potassium cyanide to recover precious metals (gold and silver) from the ore. Cyanide heap leaching is generally used to recover gold from low-grade ore while "tank" leaching is used for higher grade ore.

Heap Leaching. Since the late 1970s, heap leaching has developed into a cost-effective procedure to beneficiate a variety of low-grade, oxidized gold ores. Compared to conventional cyanidation (i.e., tank leaching), heap leaching has several advantages, including simplicity of design, lower capital and operating costs, and shorter startup times. Depending on the local topography, a heap or a valley fill method is typically employed. The sizes of heaps and valley fills can range from a few acres up to several hundred acres. The design of these leaching facilities and their method of operation are quite site-specific and may vary over time at the same site.

Heap leaching activities may involve any or all of the following steps (Bureau of Mines, 1978 and 1984; van Zyl, 1988; many others):

- Preparation of a "pad" (or base under the heap) with an impervious liner on a 1° to 6° or greater slops for drainage. No gold heap or valley fill leaches are known to operate without a liner (Hackel, 1990). Some liners may simply be compacted soils and clays, while others may be of more sophisticated design, incorporating clay liners, french drains, and multiple synthetic liners.

- Placement of historic tailings, crushed ore, or other relatively uniform and pervious material on the uppermost liner to protect it from damage by heavy equipment or other circumstances.
- Crushing and/or agglomerating the ore (agglomeration is discussed below), typically to between 1/2 and 1 inch in size, if necessary and cost-effective; some operations may leach run-of-mine ore.

- Placing the ore on the pad(s) in lifts using trucks, bulldozers, conveyors, or other equipment.

- Applying cyanide solution using drip, spray, or pond irrigation systems, with application rates generally between 0.5 and 1.0 pounds of sodium cyanide per ton of solution. This is known as the "barren" solution because it contains little or no gold.

- Collecting the solution intercepted by the impervious liner via piping laid on the liner, ditches on the perimeter of the heap, or pipes/wells through the heap into sumps at the liner surface. The recovered pregnant solution, now laden with gold (and silver), may be stored in ponds or routed directly to tanks for gold recovery, or it may be re-applied to the heap for additional leaching.

- Recovering the gold from the pregnant solution (typically containing between 1 and 3 ppm of gold).

Leaching usually continues until the gold concentration in pregnant solution falls below about 0.005 ounces per ton of solution (Lopes and Johnston, 1988). When leaching ends, the spent ore may then be left in place (over which new lifts may be added) or detoxified and removed from the pad for disposal in a spent ore pile. The leaching cycle can range from weeks to several months, depending on the permeability, size of the pile, and ore characteristics. The “average/normal” leach cycle is approximately three months (Lopes and Johnston, 1988).

Recovery of gold from the pregnant solution is accomplished using carbon adsorption or, less commonly, by direct precipitation with zinc dust (known as the Merrill-Crowe process). These techniques may be used separately or in a series with carbon adsorption followed by zinc precipitation. Both carbon adsorption and zinc precipitation separate the gold-cyanide complex from the noncomplexed cyanide and other remaining wastes. Other less common techniques used to recover gold values include solvent extraction, direct electrowinning, and, more recently, ion exchange.

Carbon adsorption uses the Carbon-in-Column (CIC) technique in which the pregnant solution is pumped into a series of cascading columns containing activated carbon. The activated carbon collects gold from the cyanide leachate until it contains between 100 and 400 ounces of gold per ton of carbon, depending on the individual operation. The precious metals are then stripped from the carbon by elution with the use of a boiling caustic cyanide stripping solution (1.0 percent NaOH and 0.1 percent NaCN) or other similar solutions. Gold in the pregnant eluate solution may be electrowon or zinc precipitated.

Electrowinning (or electrodeposition) uses stainless or mild steel wool, or copper, as a cathode to collect the gold product. After two or more cycles of electrodeposition, the steel wool must be removed. The steel wool or electrowinning sludge, laden with gold value, is fluxed with sodium nitrate, fluorspar, silica, and/or sodium carbonate and melted in a crucible furnace for casting into bullion.

Although carbon adsorption/electrowinning is the most common method of gold recovery in the United States, zinc precipitation is the most widely used method for gold ore containing large amounts of silver. Because of its simple and efficient operation, the Merrill-Crowe process is used at the 10 largest gold producing mines in the world, all of which are in South Africa. In zinc precipitation operations, pregnant solution (or the pregnant eluate stripped from the activated carbon) is filtered and combined with metallic zinc dust resulting in a chemical reaction which generates a gold precipitate (Bureau of Mines, 1984). The solution is forced through a filter that removes the gold metal product along with any other precipitates. The gold precipitate recovered by filtration is often of sufficiently high quality (45 to 85 percent gold) that it can be dried and smelted in a furnace to make doré (unrefined metals).

Wastes associated with gold heap leaching activities include spent ore, spent leaching solutions, electrowinning sludges, and detoxification rinse water.

Tank Leaching. Tank leaching techniques for gold recovery are preferred over heap leaching for higher-grade ores, typically those with gold values averaging over 0.04 troy ounces per ton of ore. In tank leaching operations, primary leaching takes place in a series of tanks, often in the mill building, rather than in heaps. Finely ground gold ore is slurried with the leaching solution in tanks. The resulting gold-cyanide complex is then adsorbed on activated carbon. In the Carbon-in-Pulp (CIP) method, leaching and adsorption occur in two separate series of tanks; in the Carbon-in-Leaching (CIL) method they occur in a single series. In either, the pregnant carbon then undergoes elution, followed either by electrowinning or zinc precipitation, as described previously. The recovery efficiencies attained by tank leaching are significantly higher than for heap leaching.

Both the CIP and CIL methods produce fine tailings, which are generally pumped to an impoundment. The composition of the tailings reflects the characteristics of the ore body, along with small (but sometimes significant) amounts of residual cyanide. In some cases, the tailings may be treated to neutralize cyanide prior to disposal. Other wastes generated by facilities that use tank leaching include: spent leaching solutions, electrowinning sludges, and detoxification rinse water.

Copper Dump Leaching

Solution mining techniques are being used increasingly for the recovery of copper and currently account for approximately 30 percent of domestic copper production. Two-thirds of all United States copper mines employ various types of solution operations (Weiss, 1985). Sulfuric and hydrochloric acid leaching at atmospheric pressure are the most common types of copper leaching.

Dump leaching refers to the leaching of oxide and low-grade sulfide ore in (typically) unlined piles. Copper dump leaches are frequently massive, with piles ranging in size from 20 to hundreds of feet in height and often covering hundreds of acres and containing millions of tons of ore. These operations involve the addition of leaching solution, collection of pregnant leach solution (PLS), and the extraction of copper by SX/EW or cementation. Natural precipitation/mine water are generally used to leach low grade sulfide ore, while dilute sulfuric acid is commonly used to leach oxide ores. Since widespread application of the leaching process is a relatively new process, copper mines have frequently applied leaching techniques to recover values from historic waste rock dumps. Thus, collection of PLS may not be maximized (i.e., some PLS may escape to the environment). New dump leach units are typically located and designed to prevent or minimize the loss of leach solution. Once collected, copper is commonly recovered from PLS in one of two ways; SX/EW or cementation.

The solvent extraction (SX) process is a two-stage method; in the first stage, low-grade, impure leach solutions containing copper, iron, and other base-metal ions are fed to the extraction stage mixer-settler. In the mixer, the aqueous solution is contacted with an active organic extractant (chelating agent) in an organic diluent (usually kerosene), forming a copper-organic complex. The organic phase extractant is formulated to extract only the desired metal ion (i.e., copper), while impurities such as iron or molybdenum are left behind in the aqueous phase. The barren aqueous solution, called raffinate, is typically recirculated back to the leaching units while the loaded organic solution is transferred from the extraction section to the stripping section. In the second stage, the loaded organic solution is stripped with concentrated sulfuric acid solution (spent electrolyte) to produce a clean, high-grade solution of copper for electrowinning.

Electrowinning (EW) is the method used to recover copper from the electrolyte solution produced by solvent extraction. Copper is plated on cathodes of stainless steel or on thin-copper starting sheets and the cathode copper is then shipped to a rod mill for fabrication. The spent acid is recycled and pumped back to the leaching operation, while some of the electrolyte is pumped to the solvent extraction process (Office of Technology Assessment, 1988; Engineering and Mining Journal, 1990).

In the past, copper produced from leach solutions was typically recovered by cementation techniques. In the cementation process, PLS flows to a precipitator pond filled with scrap iron or steel. The copper chemically reacts with, and precipitates onto the steel surfaces. The iron is dissolved into solution, and the copper precipitates out (i.e., replaces) the iron. While cementation has been a source of relatively inexpensive copper, the cement copper produced is relatively impure compared to electrowon copper and must be smelted and refined along with flotation concentrates (Beard, 1990). As a result, it has largely been replaced by SX/EW technology. Wastes associated with copper dump leaching operations include spent ore, spent leaching solutions, and SX/EW sludges.

MINERAL PROCESSING

The following paragraphs provide brief descriptions of some of the most common mineral processing practices currently employed in the United States in the alumina, copper, elemental phosphorus, ferrous metals (iron), lead, and phosphoric acid industry sectors. Mineral processing operations for minerals which are mined and processed predominantly as by-products (e.g., silver) are not discussed separately. Additionally, minerals such as gold, which may be completely or partially refined as part of the beneficiation process, are not discussed. Much of the information presented in this section was obtained from EPA's Office of Air Quality Planning and Standards document (EPA, 1985a) and the *Report to Congress on Special Wastes from Mineral Processing* (EPA, 1990).

Alumina Processing

Bauxite ore is purified to produce alumina (Al_2O_3) by the Bayer process and then is reduced to elemental aluminum. The production of alumina and the reduction of alumina to aluminum is seldom performed at the same facility. The production of alumina from bauxite ore using the Bayer process generally follows five steps. First the bauxite ore is dried, crushed, and screened and then mixed with a caustic alkaline solution (NaOH). The second step is the routing of slurried ore to digesters, where the aluminum is heated and solubilized as sodium aluminate ($Na_2Al_2O_3$). In the third step, the solution is cooled and purified. Purification is performed by separation and washing to remove sodium hydroxide and other impurities (known collectively as red mud). The fourth step is the precipitation of the cooled and purified aluminum hydroxide using sodium hydroxide seed crystals. The aluminum hydroxide precipitate is filtered, then concentrated by evaporation, resulting in a filter cake. The fifth and final step is the calcination of the hydroxide filter cake to produce a crystalline form of alumina, advantageous for electrolysis.

Electrolytic reduction of alumina occurs in shallow rectangular cells, or “pots,” which are steel shells lined with carbon. Carbon electrodes extending into the pots serve as the anodes and the carbon lined steel shell is the cathode. Molten cryolite functions as both the electrolyte and the solvent for the alumina. Electrical resistance to the current passing between the electrodes generates heat and the resulting molten aluminum is deposited onto the cathode. The aluminum product is periodically tapped below the cryolite bath and fluxed to remove trace impurities.

Wastes associated with alumina processing and aluminum production include red mud (including residual water) and particulates from ore grinding and calcining during alumina processing; and gaseous and particulate hydrogen fluoride, alumina, carbon monoxide, volatile organics, and sulfur dioxide from the aluminum reduction operations.

Copper Processing

Primary copper processing operations include, in general, roasting, smelting, converting, fire refining in an anode furnace, and electrolytic refining. The products from each operation, respectively, are calcine, copper matte, blister copper, copper anodes, and refined copper. Smelting involves the application of heat to a charge of copper ore concentrate, scrap, and flux, to fuse the ore and allow the separation of copper from iron and other impurities. Although several types of smelting furnaces are used in the United States, all furnaces produce two separate molten streams: copper-iron-sulfide matte and slag. Slag from some smelting operations may have copper concentrations higher than the original ore and therefore may be sent to a concentrator and the concentrate returned to the smelter. The copper matte from the smelter is typically routed hot to the converter furnace where high-silica flux and compressed air or oxygen are introduced. Most of the remaining iron combines with the silica to produce converter slag and additional air or oxygen is blown in to oxidize the sulfur and convert copper sulfide to blister copper, which can be 99 percent pure. The sulfur dioxide gas stream reports to an acid plant for sulfuric acid production.

To purify blister copper further, fire refining and electrolytic refining are used. In fire refining, blister copper is placed in an anode furnace, flux is usually added, and air is blown through the molten mixture to oxidize remaining impurities, which are removed as slag. The fire refined copper is cast into anodes; further electrolytic refining separates copper from impurities by electrolysis in a solution containing copper sulfate and sulfuric acid. The copper is dissolved from the anode and deposited at the cathode which can later be remelted to produce bars, ingots, or slabs which are 99.95 to 99.97 percent pure.

Wastes associated with copper processing include smelter slag; particulate and sulfur dioxide emissions; and process water from cooling, general wash-down activities, and air pollution control devices (scrubber blowdown).

Elemental Phosphorus Processing

Elemental phosphorus is used as a process input to produce a wide array of phosphorus chemicals. As a chemical manufacturing feedstock, it may be used directly, or oxidized and condensed to produce a high-purity “furnace-grade” phosphoric acid (see phosphoric acid production discussed below). In elemental phosphorus processing, sized phosphate rock or sintered/agglomerated phosphate rock fines are introduced into an electric arc furnace together with coke (a reducing agent) and silica (a flux) . The phosphorus within the rock is both liberated from the matrix and chemically reduced by the operation. The process generates calcium silicate slag and ferrophosphorus, which are tapped from the bottom of the furnace in molten form, and carbon monoxide (CO) off-gases, which contain volatilized phosphorus. The gas is treated using a precipitator to remove impurities and the cleaned gas, still containing the gaseous phosphorus, is condensed using water to produce liquid elemental phosphorus.

Wastes associated with elemental phosphorus processing include furnace slag; phosphoric acid mist; phosphoric acid scrubber water; and process wastewaters.

Phosphoric Acid Production

There are two processes for producing phosphoric acid: (1) the wet process, and (2) the thermal (furnace) process. The wet process is employed when the acid is to be used for fertilizer production, while the thermal process is employed when a higher purity acid is required for high grade chemicals and food products. The wet process consists of three operations: digestion, filtration, and concentration. Beneficiated phosphate rock is fed to a reactor with 93 to 98 percent sulfuric acid, which decomposes the phosphate rock. The product of this operation is a slurry that consists of the phosphoric acid (32 percent) and a suspended solid, calcium sulfate, commonly known as phosphogypsum. The slurry is routed to a filtration operation where the suspended phosphogypsum is separated from the acid solution. The acid isolated during filtration is concentrated through evaporation to produce "merchant-grade" (54 percent) phosphoric acid. The phosphogypsum is directed to settling ponds.

In the thermal process, elemental phosphorus is burned (oxidized) in a combustion chamber to form phosphorus pentoxide. The phosphorus pentoxide is hydrated with dilute acid or water to produce phosphoric liquid acid and mist. The final step is to remove the phosphoric acid mist from the gas stream by precipitation. The thermal process usually yields a product of 75 to 85 percent phosphoric acid.

Wastes generated during the wet process include phosphogypsum; process wastewater; gaseous fluorides (silicon tetrafluoride and hydrogen fluoride); and a small amount of particulate matter from process equipment and filters. The primary wastes generated during the thermal process are phosphoric acid mist and process waters from cooling and air pollution control devices.

Ferrous Metals Processing

Ferrous metals processing consists of smelting and iron and steel production. Iron ore, limestone, flux, coke, and recycled flue dust and sinter are usually fed to an updraft sintering machine which prepares the ore for smelting. The resulting charge is fed to a blast furnace (95% of which are submerged electric arc furnaces) which consists of a refractory-lined steel shaft in which a charge is continuously added to the top through a gas seal. Iron and steel scrap may also be added in small amounts. Preheated air is blown into an area near the bottom of the furnace. The coke is combusted to produce carbon monoxide, the iron ore is reduced to iron by the carbon monoxide, and the silica and alumina in the ore and coke ash are fluxed with limestone to form a slag that absorbs much of the sulfur from the charge. Molten iron and slag are intermittently tapped from the bottom of the hearth. The slag is drawn off and the product, pig iron, is removed, cooled, and crushed and transported to a steel mill operation. Steelmaking processes convert pig iron, scrap, or direct-reduced iron, or mixtures of these, into steel in a basic oxygen furnace that lowers the carbon and silica content and removes impurities.

Wastes associated with ferrous metals and ferroalloy processing include blast and basic oxygen furnace slag; particulate, sulfur dioxide, carbon monoxide, and organic emissions; and process waters from cooling, general wash-down activities, and air pollution control devices (scrubber blowdown).

Lead Processing

Primary lead processing consists of smelting (blast furnace and dross furnace operations) and refining operations. Ore, limestone, flux, coke, recycled flue dust, and sinter are usually fed to an updraft sintering machine which prepares the ore for smelting by lowering the sulfur content by nearly 85 percent. Sintering also provides sulfur dioxide gas for sulfuric acid production. In the smelting process, sintered ore concentrate is introduced into a blast furnace along with coke, limestone, and other fluxing materials; the lead is reduced, and the resulting molten material separates into four layers: speiss and matte, two distinct layers of materials which contain recoverable concentrations of copper, zinc, and minor metals; blast furnace slag; and lead bullion (98 percent lead). The speiss and matte are either processed at the smelter for their metal content or sold to copper smelters for recovery of copper and precious metals. The lead bullion is then drossed to remove lead and other metal oxides, which solidify and float on the lead bullion. The solidified material (referred to as dross), is treated in a reverberatory furnace to concentrate the copper and other metal impurities before being routed to copper smelters for their eventual recovery. The lead bullion is further refined by operations which continue the process of removing various saleable metals and impurities. The refined lead is then cast into ingots for distribution.

Wastes associated with lead processing include blast and dross furnace slag; process wastewaters generated from cooling and general wash-down activities, and air pollution control devices (scrubber blowdown); and particulate, sulfur dioxide, lead, and organic emissions.

WASTE AND MATERIALS MANAGEMENT

This section provides an overview of the waste and materials management practices typically used in the mining industry. Selection of individual approaches is highly dependent on site-specific conditions. Further, wastes and meterials are commonly co-managed in on-site units.

Mine Water

Water removed from a mine to gain or facilitate access to an ore body is known as “mine water.” Mine water can originate from precipitation, flows into pits or underground workings, and/or groundwater aquifers that are intercepted by the mine. Mine water is only a waste if it is discharged to the environment via a point source. Mine water can be a significant problem at many mines, and enormous quantities may have to be pumped continuously during operations. When a mine closes, removal of mine water generally ends. However, underground mines can then fill (or partially fill) and mine water may be released through adits, or through fractures and fissures that reach the surface. Surface mines that extend below the water table fill to that level when pumping ceases, either forming a “lake” in the pit or inundating and saturating fill material. Pumped mine water is typically managed in on-site impoundments (often within the mine workings or tailings impoundments). Collected water may be allowed to infiltrate/evaporate, used as process make-up water or for other on-site applications such as dust control, and/or discharged to surface water subject to NPDES requirements.

Mine water can have environmentally significant concentrations of heavy metals and TDS, elevated temperatures, and altered pH, depending on the nature of the ore body and local geochemical conditions. In addition, mine water can acidify over time as sulfide minerals are exposed to water and air, resulting in acid mine drainage (AMD); the potential for acid drainage can cause significant threats to surface and groundwater quality/resources during active mining and for decades after operations cease.

Waste Rock

Both underground and surface mining operations generate “waste rock.” Waste rock consists of non-mineralized and low-grade mineralized rock removed from above or within the ore body during extraction activities. Waste rock is typically disposed in large piles or dumps in close proximity and down-slope of the point of extraction. Waste rock dumps may be loosely categorized as valley fills, cross valley fills, side-hill fills, or heaped fills (or piles) (British Columbia Mine Dump Committee, 1991). Each of these names derives from the particular topographical feature exploited for waste containment. Regardless of the layout of the unit, waste rock dumps are generally constructed on unlined terrain, with underlying soils stripped, graded, or compacted depending on engineering considerations. Such conditions may include steep foundations of unconsolidated material or partially saturated terrain that may not support the weight of fill material. Rock is generally hauled to the face of the unit in trucks or by conveyor systems and then dumped. Surface grading of fill material is typically performed to provide haulage trucks access to the working face. Most commonly, waste rock is deposited at the angle-of-repose.

Depending on site hydrology and regulatory constraints, drainage systems may be incorporated into dump foundations. In areas of groundwater intrusion or where catchment areas channel substantial surface water flows into the dump, drainage systems help to prevent instability due to foundation failures from saturation (BCMDC, 1991). Drainage systems may be constructed of gravel-filled trenches or gravel blankets, with capacity and configuration determined according to site-specific conditions. Dump toe drains may be particularly favored to reduce pore pressure near the face of the structure to prevent toe spreading or local slumping.

Tailings

Most of the ore extracted at hardrock mines ultimately becomes mill tailings requiring disposal. Because tailings produced by mills are usually in slurry form, disposal of slurry tailings in impoundments made of local materials is the most common and economical method of disposal. There are four main types of slurry impoundment layouts: valley impoundments, ring dikes, in-pit impoundments, and specially-dug pits (Ritcey, 1989). The impoundment design choice is primarily dependent upon natural topography, site conditions, and economic factors. Other things being equal, it is economically advantageous to use natural depressions to contain tailings. Among other advantages are reduced dam size, since the sides of the valley or other depression serve to contain tailings.

There are two general classes of impounding structures: water-retention dams and raised embankments. The choice of impounding structure is influenced by economics and site-specific factors including the characteristics of the mill tailings and effluent. In general, impoundments are designed to control the movement of fluids both vertically and horizontally. Regardless of the layout of the impoundment, at most facilities ponded water is decanted from tailings ponds and recirculated to the mill for reuse in beneficiation processes. In general, two methods are available for decanting pond water: decant towers and pumping (usually from floating barges). In some cases, tailings are dewatered or dried and disposed of in piles. However, except under special circumstances, dry disposal methods can be prohibitively expensive due to additional equipment and energy costs. The advantages of dry disposal include minimizing seepage volumes, the land needed for an impoundment or pile, and the ability to conduct simultaneous tailings deposition and reclamation.

In addition to disposal in impoundments and piles, slurried tailings are sometimes disposed of in underground mines as backfill to provide ground or wall support. This decreases the above-ground surface disturbance and can stabilize mined-out areas. To increase structural stability, cement may be mixed with the sand fraction before backfilling. Subaqueous tailings disposal, which has been practiced primarily in Canada, is the placement of tailings below a permanent water surface such as a lake or ocean. Subaqueous disposal is practiced primarily to minimize the acid generating potential of tailings by not allowing sulfide ore to oxidize.

Leaching Operations

When leaching operations cease, the spent ore in the heap or dump is usually managed in place. Where on-off pads are used, however, spent ore is removed from heap leach pads for disposal in on-site piles or dumps (similar to waste rock dumps). Prior to final reclamation (or prior to ore removal from on-off pads), spent ore generally must be detoxified. This is typically accomplished by repeated rinsing with water, usually mine water or mill wastewater. At gold leaching operations, hydrogen peroxide or other oxidants may be added to rinse waters to oxidize residual cyanide. The time necessary for rinsing heaps is highly variable, ranging from a few days for some on-off heaps to months or years for other heaps and dumps.

Following detoxification, heaps and dumps may be regraded to more stable long-term configurations. If present, liners may be punctured and the heap/dump covered with topsoil and reclaimed. In some cases, heaps/dumps may require capping to reduce leaching of heavy metals. Because of the large volumes of materials typically placed in heap/dump units, any potential long-term environmental problems (associated with waste management) should be investigated and addressed during initial unit design rather than after leaching ceases and materials become wastes.

Solution ponds are potential sources of acid/metal releases to ground and surface water. Ponds associated with precious metal leaching operations and newer copper facilities are generally lined with synthetic materials (although liners are often susceptible to failure). At older copper sites, solution ponds may be unlined or lined only with natural materials. At closure, ponds are frequently backfilled. Pond liners may be removed, folded over and sealed to encapsulate sludges or other wastes, punctured, or otherwise handled, depending on applicable regulatory requirements.

When leaching operations cease, non-cyanide bearing leach solutions may either receive simple neutralization or pH adjustment and metals precipitation treatment. Cyanide-bearing solutions typically receive some form of cyanide destruction and neutralization treatment. These treated wastestreams may then be allowed to infiltrate/evaporate or may be re-applied to disturbed mine areas.

Mineral Processing Wastes and Materials

Slags from thermal mineral processing operations (copper and lead smelting and refining, blast furnaces, and elemental phosphorus production) are generally managed in unlined, on-site piles. Depending on the industry sector and the specific waste characteristics, significant quantities may be available for re-use in construction applications. For example, all of the slag produced by several elemental phosphorus operations is sold for off-site re-use.

Phosphogypsum and phosphoric acid production wastewater are co-managed in “phosphogypstacks.” These massive units have historically been unlined to allow drainage through the stacks. The pH of stack water is typically less than one (reflecting residual phosphoric and sulfuric acid). Recycle/re-use alternatives for phosphogypsum have generally proven to be unfeasible and/or uneconomical.

Red muds from alumina production are disposed of in impoundments. Existing waste management units typically have runon/runoff controls and some have leachate collection systems (to address seepage). While research suggests that red muds could potentially be reused (as a blast furnace feed, in construction applications, etc.), little or no red mud waste has been re-used to date.

ANCILLARY OPERATIONS

In addition to the wastes described above, extraction, beneficiation, and processing of minerals generate other wastes that are not uniquely related to mining, such as spent solvents and used oil. Large mining operations may operate hundreds of vehicles ranging in size from light trucks to immense earth moving vehicles. Vehicle and equipment maintenance activities generate large quantities of used oils and lubricants, solvents, antifreeze, tires, and wash waters. Raw material storage for maintenance activities also requires that large inventories must be maintained, including above and underground fuel tanks. If the facility is regulated by a storm water permit, a Spill Prevention Countermeasure and Control (SPCC) plan as well as a Storm Water Pollution Prevention Plan (SWPPP) are required.

In addition to the wastes already mentioned, wastes not uniquely related to mining include but are not limited to: PCBs (transformers, capacitors, and/or hydraulic fluid); vessel cleanouts; tank bottoms; empty or crushed drums; filters; pigging wastes; sewage/sanitary wastewaters; fossil fuel boiler wastes (boiler blowdown, refractory brick ash, etc.); water pollution control sludges, blowdown, etc.; air pollution control dusts, sludges, filters, etc.; drilling fluids/muds; solid wastes (i.e., garbage); construction and demolition wastes; filter washing wastes; and laboratory wastes.

These wastes, as well as hazardous mineral processing wastes, may be commingled with Bevill wastes such as tailings, in tailings ponds or other units. Aside from possible RCRA compliance issues, managing these wastes in mining units may cause potential impacts to the environment. Where applicable, management of these wastes should be specifically addressed in the NEPA documentation for each mining operation. In addition, proper monitoring of storage and disposal units for these wastes should be described.

CHAPTER III

POTENTIAL ENVIRONMENTAL IMPACTS

INTRODUCTION

This chapter describes the potential environmental impacts associated with extraction, beneficiation, and mineral processing operations. The mining industry and its potential environmental impacts are unusual in a number of ways; of these, three may be the most important. First, many of the potential impacts are unique to the industry (acid rock drainage, releases from cyanide leaching units, structural failure, etc.). Second, many of the impacts may be manifested years or decades after mining ends and can intensify over time. Finally, the nature and extent of impacts from mining operations are based on factors that are specific to the location (including geology, hydrogeology, climate, human and wildlife populations, etc.). Impacts from similar types of operations can range from minimal to extensive, depending on local conditions. These factors emphasize the need for a full understanding of baseline conditions and careful planning to avoid/mitigate potential impacts.

As in all major industrial operations, careful design and planning play a critical role in reducing or mitigating potential impacts. In the case of the mining industry, the three characteristics that distinguish it from other industries make initial design and planning even more crucial. Design and operation plans, including measures to mitigate potential environmental impacts, are often only conceptual at the time of permitting. This makes it extremely difficult to delineate the types of information and analyses that are necessary to assess potential impacts.

The following sections describe potential impacts to surface and ground water, air, and ecosystems associated with mining operations, along with possible mitigation measures. The final section of this chapter identifies (by type of operation) questions that reviewers can ask to determine whether the potential impacts to all media have been fully considered in the NEPA process.

POTENTIAL IMPACTS ON SURFACE WATER

Suspended solids and toxic pollutants (primarily metals, sulfates, and nitrates) can be released to surface water from mining operations. Because of the large area of land that is disturbed by mining operations and the large quantities of earthen materials exposed at sites, erosion frequently is a primary concern at hardrock mining sites. Erosion control must be considered from the beginning of operations through completion of reclamation. Erosion may cause significant loadings of sediments (and any entrained chemical pollutants) to nearby streams, especially during severe storm events, as well as high snow melt periods. While acid rock drainage (ARD) can enhance contaminant mobility by promoting leaching from exposed wastes and mine structures (see Chapter IV), releases can also occur under neutral pH conditions. Primary sources of pollutants from hardrock mining operations include underground and surface mine workings; overburden and waste rock piles; tailings piles and impoundments; direct discharges from conventional milling/beneficiation operations; leach piles and processing facilities; blowdown from smelting and refining operations, phosphogypsum piles, and chemical storage areas (due to runoff and spills). The following sections describe the discharges associated with each of these operational areas as well as potential mitigation measures. A more detailed discussion of runoff and erosion is provided in Chapter IV.

Table 3-1 provides an overview of the types of pollutants potentially found in surface water discharges (process water, mine water, seepage, and runoff) from specific industry sectors. Any evaluation of the potential impacts of a new mining operation in a watershed requires an understanding of baseline (pre-construction) conditions. Baseline studies should describe flow conditions (including seasonal variability), substrate and sediment pollutant levels, and aquatic life. A brief discussion of monitoring approaches is presented in Chapter V.

TABLE 3-1
OVERVIEW OF TYPES OF POLLUTANTS FOUND IN SURFACE WATER DISCHARGES FROM HARDROCK MINING OPERATIONS[1]

Type of Mining	Potential Pollutants of Concern in Discharges to Surface Water	Typical Treatment
Iron	Asbestos, arsenic, copper, and iron	Settling ponds and flocculation
Copper, Lead, Zinc, Silver, Molybdenum and Gold (excluding cyanide leaching operations)	Aluminum, antimony, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, thallium, and zinc	Recycling/reuse and settling/precipitation ponds
Aluminum	None found at high concentrations	Not Applicable
Tungsten	Copper, lead, and zinc	Recycle (mines have generally been located in arid regions)
Mercury	Most toxic metals	Evaporation ponds and/or recycle/reuse
Uranium	Radium 226	Evaporation; ion exchange; flocculation; settling; and recycle/reuse
Antimony	Antimony, arsenic, and asbestos	Recycle/reuse
Titanium	Most toxic metals	Settling and precipitation (lime/caustic addition)
Vanadium	Mercury, arsenic, cadmium, chromium, copper, mercury, lead and zinc	Neutralization, settling and precipitation

[1] Source: EPA, 1982; Ore Mining and Dressing Development Document.

Extraction - Mine Workings

Potential Impact: During active operations where mining occurs below the water table, mine water is typically pumped from underground and surface operations and often discharged to surface water through NPDES-permitted outfalls. After operations cease, mine workings may overflow and uncontrolled mine water/runoff may be discharged. The characteristics of the ore body will affect the composition of mine water discharges. Specifically, the occurrence of ARD may cause acidic conditions and enhance pollutant mobility; however, toxic loadings can also occur under neutral conditions. Finally, residues from blasting or from fertilizer used during reclamation can cause elevated nitrate concentrations.

Development of appropriate mitigation measures for surface water discharges from mine workings requires a complete understanding of the baseline hydrogeology of the site, including bedrock and alluvial aquifers as well as the influence of fracturing. This information can be used to predict the volumes of mine water requiring management. At surface mines, proposed operators must also consider runoff contributions in planning water management. Data on the likely characteristics of mine water/runoff are necessary to evaluate the potential for re-use and/or the need for treatment prior to discharge. Where sulfide mineralization is encountered, testing for acid generation potential should be performed; see Chapter IV.

Mitigation Measures:

- Maximize evaporation and re-use of mine water in processing operations.
- For surface mines, use runon and runoff control measures, such as berms and ditches.
- Use neutralization/precipitation or other treatment practices prior to discharges. If state-of-the-art technologies or passive treatment (e.g., wetlands) will be used, pilot-scale testing and/or contingencies should be included.
- Provide for clean-up of blasting residuals (provide nitrate treatment as necessary).

- Provide for long-term (i.e., post-closure) mine water management (backfilling of workings, sealing of adits, passive and active treatment, etc.).
- Monitor discharges and surface water quality.
- Site mine water containment units to minimize the potential for surface water recharge (through alluvial materials and/or fractures).

Extraction - Waste Rock/Overburden Piles

Potential Impacts: Waste rock and overburden are typically managed in piles adjacent to the mine workings. Materials are frequently end-dumped into angle-of-repose units that are often located on the slopes of natural drainages. These units are generally unlined. Potential pollutant loadings in runoff and seepage from waste rock piles are dependent on the site-specific mineralogy; they can include sediment as well as metals, sulfates, and radionuclides. Where sulfur mineralization is present, ARD can occur.

To determine the surface water impacts associated with a proposed waste rock dump and identify potential mitigation measures, baseline environmental data and waste rock characteristics are needed. The geology of the site will establish likely waste characteristics. ARD potential should be determined where sulfide minerals are found. A complete water balance should be provided to describe the projected flows in and out of the dump (as well as an evaluation of stability and the potential for slope failure).

Mitigation Measures:

- To the maximum extent possible, backfill into dry mine workings with waste rock (where sulfide materials are present consider stabilization/cementation prior to backfilling).
- Maximize the use of overburden in reclamation. Provide for reclamation of waste rock piles.
- Collect and monitor seepage and runoff. Use Best Management Practices (BMPs) to control erosion; note that many BMPs require regular maintenance to ensure consistent performance. Where necessary, provide additional active/passive treatment for sediment and other pollutants in drainages. BMPs and containment and treatment systems should be designed to handle up to reasonable maximum flow rates.
- Where ARD is observed, reactive waste rock can be segregated and covered/encapsulated by non-reactive materials.
- Use non-reactive waste rock for on-site construction (buttresses, haul roads, etc.).
- Establish a reclamation plan based on proven techniques (use overburden as surficial material to facilitate vegetative growth, establish test plots as appropriate).
- Provide for adequate dump drainage to minimize the potential for slope failure. Use piezometers to monitor water levels/stability.
- Conduct baseline surface water monitoring and continue discharge and water quality monitoring throughout operations and closure/post-closure periods.

Beneficiation - Tailings Impoundments

Potential Impacts: Tailings impoundments are typically constructed in natural drainages (to facilitate water management). Most mines attempt to maximize re-use of tailings water in milling operations. However, impoundment designs frequently include underdrains and controlled discharges (especially in high precipitation/snow melt areas). Further, even where units are intended not to discharge, tailings impoundments are nearly always accompanied by unavoidable seepage through or beneath the dam structure. Similar to waste rock, the composition of surface water discharges from tailings is dependent on the local geology. However, fine tailings can be more susceptible to leaching/entrainment of particulates than coarser waste rock materials. Contaminants associated with the host rock often include heavy metals, arsenic, and radionuclides. ARD can occur if sulfide mineralization is encountered and may enhance metals mobility. Residual mill reagents may also be present in the tailings, however, they typically do not contribute significant pollutant loadings. Finally, where the outside slopes of dams or other units are constructed of tailings or other mining wastes, discharges and runoff from these areas can affect water quality and may require treatment.

Tailings are typically transported to impoundments by pipeline. Reclaimed water is collected from impoundments and returned to the mill by pipeline. Pipe failures may lead to surface water impacts if pipelines are located in drainages or residues contact runoff.

Development of appropriate mitigation measures for tailings impoundments necessitates an understanding of the overall water balance (including reuse, groundwater infiltration, evaporation, seepage, snow melt, and runoff). The composition of the tailings should be determined by evaluating the local geology and representative waste testing (including leachability testing). If sulfide mineralization is encountered, ARD potential should be determined.

<u>Mitigation Measures</u>:

- Ensure that the unit (and associated diversion, containment, and treatment systems) has been designed to contain the maximum reasonable storm event and to withstand even rarer events.
- For units located in drainages, consider natural and/or synthetic liners or keying units into bedrock (to minimize releases to the alluvium and subsequent recharge). Also consider liners for any seepage/runoff collection sumps/ditches outside the berm(s).
- Maximize the reclaim/reuse of tailings water.
- Regulate dosages of mill reagents (i.e., limit use to the least extent necessary). Monitor tailings water for mill reagent contamination.
- Provide adequate drainage of the berms to prevent slope failure. Monitor the phreatic surface/stability using piezometers.
- Design tailings pipelines to include secondary containment.
- Continue ARD testing throughout the operational and closure periods. Where ARD is encountered, consider the mitigation measures identified in Chapter IV.
- Collect runoff/seepage from the outer slopes of the impoundment and provide for treatment/use of BMPs as appropriate.
- Ensure that instream tailings management conforms to all Clean Water Act §402 (NPDES) and §404 (wetland/dredge and fill) requirements.

Beneficiation - Copper Dump Leach Operations and SX/EW Plants

<u>Potential Impacts</u>: Copper leaching operations are generally intended to have no surface water discharges during active leaching operations. Dumps are typically sited in natural drainages with downstream collection sumps. Pregnant solution and raffinate ponds are lined and SX/EW plant operations normally have secondary containment. However, a full understanding of the water balance and adherence to sound design standards are necessary to ensure that all drainage is collected. This is especially applicable to sites with significant variations in precipitation and snow melt. Further, any closed loop system will inevitably have spill events that can cause surface water impacts. Finally, surface water discharges are likely after leaching becomes no longer economical (to date, closure plans generally have not been developed during initial planning). Surface water discharges from copper dump

leaches are likely to be acidic and contain metals, sulfates, and other pollutants associated with the geology of the host rock. Reagents such as kerosene are used in the SX/EW process; however, the small quantities suggest that they would be generally undetected in any discharges.

<u>Mitigation Measures</u>:

- Design dump leach units to fully drain to collection areas (including both seepage and runoff). This involves ensuring a full understanding of drainage patterns and the hydrogeology of the site.

- Ensure that collection, pregnant solution, and raffinate ponds are designed to contain up to the maximum reasonable storm event. Line process ponds. As necessary, design and install secondary collection sumps to contain any solution that bypasses the primary ponds.

- Provide secondary containment for solution pipes to minimize impacts from pipe failures/spills. Develop and implement a spill response plan to lessen any impacts from releases.

- Develop a plan to collect and, as necessary, treat prior to discharge, drainage that occurs after copper recovery becomes no longer economical (at closure). Design and implement a reclamation plan based on proven techniques tailored to site conditions (topography, climate, local vegetation, etc.).

- Monitor post-closure discharges and downstream surface water quality. Parameters should be identified based on pregnant solution characteristics.

Beneficiation - Cyanide Leaching Operations

<u>Potential Impacts</u>: Cyanide heap leaches and associated processing operations can cause acute impacts to surface water through leaks or failures of containment systems. In addition, unless effective detoxification procedures are used, spent ore piles can cause releases of residual cyanide. Further, other pollutants (including heavy metals) can be mobilized in the leaching process and may be released to surface water through spills or leaks (during operations) and through seepage/runoff from spent ore (after closure). The characteristics of spent ore pile seepage/runoff will depend on the local geology and any residual effects of application of the leaching solution. Where sulfide mineralization is encountered, the potential for ARD should be investigated. Finally, cyanide degradation can also lead to nitrate contamination.

<u>Mitigation Measures</u>:

- Wherever possible, do not locate leaching operations in or near drainages, especially perennial streams supporting aquatic life.

- Ensure that pregnant and barren solution ponds and transport ditches are designed to contain all solution flows <u>and</u> any runoff/snow melt up to the maximum reasonable storm event.

- Provide double liners and leak detection systems for all heaps, ponds, and drainage ditches. Perform adequate surface preparation and design loading practices to minimize the potential for liner failure.

- Provide for testing of detoxified materials prior to disposal or abandonment to ensure cyanide levels are reduced to below levels protective of human health and the environment.

- Collect and test seepage and runoff from spent ore piles (ensuring that containment is designed to hold up to the maximum reasonable storm event). If sulfide mineralization is present, perform long-term ARD studies. Treat runoff/seepage as necessary prior to discharge. Also perform downstream water quality monitoring.

- Develop and implement a spill prevention and response plan to ensure prompt detection and clean-up of any spills.

Mineral Processing - Phosphoric Acid Production/Phosphogypstacks

Potential Impacts: Phosphogypsum from phosphoric acid production is typically slurried to "phosphogypstacks." Except for facilities located in Louisiana, no direct surface water discharges are allowed from phosphogypstacks, except during heavy precipitation events (40 CFR Part 418.10). However, discharges of overflows during precipitation events may be highly acidic with elevated concentrations of metals, sulfate, phosphorous, and radionuclides. In addition, phosphogypstacks located near surface waters may be subject to failures that can cause uncontrolled pollutant releases. Surface water impacts from infiltration/seepage can also occur through groundwater recharge.

Mitigation Measures:

- Optimize plant operations to maximize phosphoric acid recovery and minimize the phosphorous levels in/acidity of the waste.
- Determine the likely water balance for the unit (including effects of heavy precipitation) and conduct a stability analysis for the proposed design. Use piezometers to monitor stability during and after waste disposal.
- Line phosphogypstacks and provide for leak detection (to minimize recharge potential).
- Collect runoff/seepage from the outer slopes of the stacks; treat, as necessary, prior to discharge.
- Monitor upstream and downstream surface water quality.

Mineral Processing - Slag Piles and Other Wastes From Furnace Operations

Potential Impacts: Mineral processing operations generate significant quantities of slag which is typically disposed of in lined or, more often, unlined piles. Although contaminant mobility may be reduced due to the nature of the slag matrix, surface water releases may be caused by precipitation that comes into contact with the slag.

In addition, at many smelting/furnace operations, ore, coke, flux, and other materials used in mineral processing operations are stored outside. Fugitive emissions from these materials, as well as stack emissions, can contribute to on-site soils deposition. Storm water which comes into contact with stored materials or affected soils can provide a transport mechanism for releases to surface waters through entrainment or leaching. Pollutants will reflect the characteristics of the ore.

Mitigation Measures:

- Wherever possible, do not locate slag piles near drainages.
- Collect runoff/seepage from the outer slopes of the slag piles and conduct testing to determine pollutant concentrations; provide for containment and/or treatment, as necessary.
- Implement good housekeeping procedures to minimize fugitive emissions from raw material storage (e.g. provide covers).
- Install appropriate air pollution control devices to control particulate matter (see section below on mitigation measures for air emissions). Provide for recycling/re-use and/or proper management of air pollution control wastes.

POTENTIAL IMPACTS ON GROUNDWATER

Releases from mining operations can have significant impacts on groundwater quantity and quality. Drawdown associated with mine dewatering can reduce the availability of water for domestic water supplies and other uses, and can also affect wetland habitats. Releases of heavy metals, sulfates, nitrates, and radionuclides from mining materials can contaminate aquifers. Spills and leaks of cyanide solutions from leaching operations have also impacted groundwater quality.

To determine the potential for groundwater impacts, it is essential that the EA/EIS include a detailed description of the site hydrogeology, including both alluvial and bedrock aquifers as well as the influences of fracturing. NEPA documentation should also describe the likely characteristics of waste materials (including ARD potential) and how reagent use/handling may contribute to subsurface releases. This information will serve to predict potential groundwater impacts and guide design and implementation of appropriate mitigation measure during both active operations and closure/post-closure.

Extraction - Mine Workings

Potential Impact: Contact with exposed mine workings can lead to contamination of mine water. Pollutants can include heavy metals, sulfate, arsenic, and radionuclides. Metals releases can be enhanced by acid mine drainage (AMD) (where there is sulfide mineralization); although leaching can occur both under acidic and neutral conditions. Mine water can also be contaminated by blasting residuals (i.e., causing elevated nitrate concentrations). Infiltration of mine water from underground and surface workings/management units can lead to contamination of aquifers (some mining operations use infiltration ponds as a primary mine water management practice). Further, infiltration of groundwater into mine workings and subsequent use in processes, evaporation, and/or discharge can cause aquifer drawdown (currently being observed in the Carlin Trend area in northeastern Nevada). These effects can lead to diminished drinking water supplies as well as loss of riparian zones and wetlands associated with lowered groundwater levels.

Mitigation Measures:

- Maximize evaporation and re-use of mine water in on-site operations.
- Use neutralization/precipitation or other treatment practices, as necessary, prior to allowing re-infiltration. If state-of-the-art technologies or passive treatment (e.g., wetlands) will be used, pilot-scale testing and/or contingencies should be included.
- Provide for clean-up of blasting residuals (provide nitrate treatment as necessary).
- Provide for long-term (i.e., post-closure) mine water management (backfilling of workings, sealing of adits, passive and active treatment, etc.).
- Establish baseline groundwater chemistry and perform groundwater monitoring during operations and after closure. As appropriate, monitor nearby water supply wells.
- In areas where drawdown is a concern, ensure that the hydrogeology/water balance is determined prior to approving operations (including cumulative effects of all operations within a region). As appropriate, limit mining/mine water generation in areas where water supplies are critical. Use pumped water from dewatering to recharge aquifers (as long as water quality is protected).

Extraction - Waste Rock/Overburden Piles

Potential Impacts: Waste rock and overburden are typically managed in piles adjacent to mine workings. Precipitation that infiltrates waste rock piles can directly impact the underlying groundwater. In addition, seepage and runoff that flow from the pile can infiltrate soils and also affect groundwater quality. Potential pollutant loadings to groundwater from waste rock piles are dependent on the site-specific mineralogy, however, they can include metals, sulfates, and radionuclides. Where sulfur mineralization is present, ARD can occur. To determine the potential for groundwater impacts, it is necessary to collect data on the baseline hydrogeology (including aquifer depth and quality). The characteristics of the waste rock and the expected water balance (inflows and outflows from the pile) should also be determined.

Mitigation Measures:

- To the maximum extent possible, backfill into dry mine workings with waste rock (where sulfide materials are present, consider stabilization/cementation).
- Collect and monitor mine dump drainage (french drains are often used). Where necessary, provide active/passive treatment for pollutants. Containment and treatment systems should be designed to contain up to reasonable maximum flow rates.
- Use runon controls to minimize the potential for infiltration.
- Where ARD is observed, reactive waste rock can be segregated and covered/encapsulated by non-reactive materials (to prevent contact with runoff/infiltration).
- Establish a reclamation plan based on proven techniques (use overburden as surficial material to facilitate vegetative growth).
- Conduct baseline groundwater monitoring and continue monitoring throughout operations and closure/post-closure periods.

Beneficiation - Tailings Impoundments

Potential Impacts: Tailings impoundments are typically constructed in natural drainages (to facilitate water management). Newer tailings impoundments may be lined (with synthetic or natural materials) or keyed into bedrock. However, some tailings water often infiltrates into groundwater. Further, outside of the impoundment, releases to groundwater can occur from infiltration of seepage and/or runoff from the outside slopes. The composition of tailings water/infiltration can reflect residual mill reagents. However, contributions from these chemicals are generally small. Instead, pollutants in tailings are typically representative of the geology of the ore body and may include metals, sulfates, and radionuclides. Where sulfide ore is beneficiated, ARD may enhance pollutant mobility.

Mitigation Measures:

- Ensure that the unit (and associated diversion, containment, and treatment systems) has been designed to contain up to the maximum reasonable storm event.
- Install natural and/or synthetic liners or key the unit into bedrock. Also consider liners for any seepage or storm water drainage collection systems outside the unit.
- Maximize the reclaim/reuse of tailings water.
- Regulate dosages of mill reagents (i.e., limit use to the least extent necessary). Monitor tailings water for mill reagent contamination.
- Design tailings pipelines to include secondary containment.
- Conduct upfront testing to determine tailings water composition (to identify the need for mitigation/treatment). Continue waste testing during operations. Perform baseline groundwater monitoring and continue well monitoring during the operating and closure/post periods.

- Continue ARD testing throughout the operational and closure periods. Where ARD is encountered, consider material segregation and/or encapsulation to minimize contact with infiltration or liners/drainage systems to avoid releases to groundwater.

Beneficiation - Copper Dump Leach Operations and SX/EW Plants

Potential Impacts: Copper leaching operations are generally intended to have no groundwater discharges during active leaching operations. Pregnant solution and raffinate ponds are lined and SX/EW plants operations normally have secondary containment. However, adherence to sound design standards are necessary to ensure that all drainage is collected. Further, any closed loop system will have spill events that can cause groundwater impacts. Groundwater discharges can also occur after leaching no longer becomes economical. Groundwater discharges from copper dump leaches are likely to be acidic and contain metals, sulfates, and other pollutants associated with the geology of the host rock.

Mitigation Measures:

- Design dump leach units to fully drain to lined collection areas (including both seepage and runoff). This involves ensuring a full understanding of drainage patterns and the hydrogeology of the site.
- Ensure that collection, pregnant solution, and raffinate ponds are designed to contain up to the maximum reasonable storm events. Line process ponds and provide for leak detection. As necessary, design and install secondary collection sumps to contain any solution that bypasses the primary ponds.
- Develop and implement a spill response plan to lessen any impacts from releases.
- Develop a plan to collect and, as necessary, treat prior to discharge, any drainage after copper recovery becomes no longer economical (at closure). If sulfide ores are leached, provide for long-term ARD mitigation, as appropriate.
- Perform baseline groundwater monitoring and conduct upgradient and downgradient groundwater quality monitoring during active operations and closure/post-closure.

Beneficiation - Cyanide Leaching Operations

Potential Impacts: Cyanide heap leaches and associated processing operations can cause impacts to groundwater through leaks or failures of containment systems. While heaps and processing units are typically lined, leaks have occurred at many operations. This can result in releases of cyanide, nitrates (products of cyanide degradation), and other pollutants (metals) that are characteristic of the ore body. In addition, infiltration from spent ore piles may be a source of pollutants.

Mitigation Measures:

- Wherever possible, do not locate leaching operations near drinking water supplies.
- Ensure that pregnant and barren solution ponds and transport ditches are designed to contain all solution and any runoff up to the maximum reasonable storm event (to prevent overflow and uncontrolled infiltration/snow melt).
- Provide double liners and leak detection systems for all heaps, ponds, and drainage ditches. Perform adequate surface preparation and design loading practices to minimize the potential for liner perforation.
- Collect and test seepage and runoff from spent ore piles (ensuring that containment is designed to hold up to the maximum reasonable storm event). If necessary, line piles and treat collected drainage. If sulfide mineralization is present, perform long-term ARD studies.

- Develop and implement a spill prevention and response plan to ensure prompt detection and clean-up of any spills.
- Determine baseline hydrogeology (including aquifer depth and quality). Conduct monitoring downgradient of process units during operations and spent ore piles during operations and after closure.

Beneficiation - *In Situ* Mining

Potential Impacts: In hardrock mining, *in situ* methods are especially prevalent in the copper and uranium sectors. In the copper industry, leaching solution can be injected into historic underground workings that were mined prior to the availability of SX/EW technologies. In the uranium sector, oxygen and carbon dioxide gases are commonly injected for uranium recovery. Groundwater impacts can occur where leaching solutions bypass recovery systems. Potential contaminants will reflect the geology of the ore body/host rock, including metals, sulfates, radionuclides, and the leach solutions. Contaminant mobility can be enhanced by the acidic solutions used in copper operations.

Mitigation Measures:

- Ensure proper production well installation/completion to avoid uncontrolled solution releases. Provide for adequate well abandonment.
- Perform a detailed characterization of the hydrogeology of the site to guide design of recovery systems and determine the potential for releases.
- Carefully monitor pumping pressures of solutions entering and leaving deposits to assure that solutions are not migrating into groundwater.
- Line surface collection systems and provide for leak detection. Design collection systems to contain the maximum volumes of leaching solutions as well as precipitation/runoff/snow melt.

Mineral Processing - Phosphoric Acid Production/Phosphogypstacks

Potential Impacts: Phosphogypsum from phosphoric acid production is typically slurried to phosphogypstacks. The pH of the slurried solution and stack pond water is often less than 1. Seepage of residual water/precipitation through these units can contaminate underlying aquifers. Metals and sulfate mobility from the gypsum waste will be enhanced by the acidic conditions in the stack. Further, radionuclides associated with phosphate rock may also be released.

Mitigation Measures:

- Optimize plant operations to maximize phosphoric acid recovery and minimize the phosphate levels in/acidity of the waste.
- Avoid locating phosphogypstacks near domestic water supply wells
- Line phosphogypstacks and provide for leak detection; continue drainage control after waste disposal ceases (as long as 30 years may be required for stacks to completely drain).
- Collect runoff/seepage from the outer slopes of the stacks.
- Conduct baseline groundwater monitoring, and monitor upgradient and downgradient wells during active operations and closure/post-closure.

Mineral Processing - Slag Piles and Other Wastes From Furnace Operations

Potential Impacts: Many mineral processing operations generate significant quantities of slag which is typically disposed of in lined or, more often, unlined piles. Although contaminant mobility may be reduced due to the nature of the slag matrix, infiltration of runoff and seepage that contacts slag can impact underlying groundwater. In addition, infiltration may become contaminated by contact with soils that are affected by deposition of fugitive and/or stack emissions.

Mitigation Measures:

- Install natural and/or synthetic liners for slag piles. Also consider liners for any seepage or storm water drainage collection systems outside the piles.
- Conduct baseline groundwater monitoring, and monitor upgradient and downgradient wells during active operations and closure/post-closure.
- Install appropriate air pollution control devices to control particulate matter (see section below on mitigation measures for air emissions). Provide for recycling/re-use and/or proper management of air pollution control wastes.

POTENTIAL IMPACTS ON AIR

Emissions Associated with Extraction

Potential Impacts: A primary air pollutant of concern at mining sites is particulate matter. In many of the processes associated with mining activities, a significant portion of the mass of particulate matter is made up of large particles, those with diameters greater than 10 micron. This coarse particulate matter usually settles gravitationally within a few hundred meters of the source. The smaller particle size fractions, however, can be carried by wind for great distances and may be deposited on or near populated areas. As a result, human health and/or environmental problems may arise through either direct inhalation, soil deposition, or accumulation within a water body. Relatively simple control techniques can be used to limit the amount of particulate matter that is released from these activities.

Mitigation Measures:

- Ore crushing and conveyors can be a substantial source of fugitive dust, and control generally involves water sprays or mists in the immediate area of the crusher and along conveyor routes or enclosing the conveyor systems.
- Loading bins for ore, limestone, and other materials also generate dust. Again, water sprays are typically used.
- Blasting generates dust that can be, and sometimes is, controlled with water sprays.
- Equipment and vehicle travel on access and haul roads is a major source of fine and coarse dust. Most mines use water trucks to dampen the surface periodically.
- Waste rock dumping can generate dust, but this generally consists of coarse particles that settle out rapidly with no other controls.
- Wind also entrains dust from dumps and spoil piles, roads, tailings (either dry as disposed or the dry portions of impoundments), and other disturbed areas. Spray from water trucks is often used when the mine is operating. During temporary closures and particularly after the active life, stabilization and reclamation are aimed in part at reducing fugitive dust emissions. Rock and/or topsoil covers, possibly with vegetative covers, can be effective controls.

Air Emissions Associated with Beneficiation and Mineral Processing

Potential Impacts: In nearly all mineral beneficiation and processing operations, ore preparation activities such as milling and grinding generate substantial quantities of particulate matter which routinely require control devices. Particulate matter is also prevalent when furnaces of all types (electric arc, basic oxygen, open hearth, etc.) are used. Activities such as sintering, smelting, tapping, product handling, and many others produce significant quantities of particulate mater which may escape as fugitive emissions or may be routed to a control device. In addition to particulate matter, beneficiation and mineral processing operations can generate large quantities of sulfur dioxide, carbon monoxide, and organic emissions which require the use of control devices. Without proper control, emissions from these operations can have a significant impact on air quality, terrestrial ecosystems, and aquatic resources.

Mitigation Measures: The primary control devices used for particulate matter emissions are centrifugal collectors (i.e., cyclones), low and high pressure wet scrubbers, fabric filters, wire mesh contractors, wet and dry electrostatic precipitators (ESPs), and baghouses. Efficiencies of these control devices vary from 80 to 99.9 percent. The mineral processing discussion in Chapter II listed the specific emission sources associated with each processing sector. The following paragraphs describe the control devices commonly used in each. This information was obtained from EPA's Office of Air Quality Planning and Standards (EPA, 1985a) and the *Report to Congress on Special Wastes from Mineral Processing* (EPA, 1990).

Alumina Processing

Various dust collection devices including centrifugal collectors, multiple cyclones, ESPs, and wet scrubbers have been used to control particulate matter emissions from calcining and ore grinding and handling operations. To control gaseous hydrogen fluoride and particulate fluorides one or more types of wet scrubbers are commonly applied. Gaseous and particulate fluorides are also controlled by passing the pot offgases through the incoming alumina feed which absorbs fluoride. This technique has an overall efficiency of 98 - 99 percent. Baghouses are then used to collect residual fluorides entrained in the alumina. Scrubber systems are also effective in removing SO_2 emissions.

Copper Processing

Particulate matter and SO_2 are the principal air contaminants emitted by primary copper smelters. Single stage ESPs are widely used to control emissions from roasters, smelting furnaces, and converters. “Hot” ESPs are effective in removing condensed particulate matter present in gaseous effluents but are relatively ineffective in reducing volatile emissions such as sulfuric acid mist. Therefore, in these cases, the gas stream is commonly cooled and directed through an additional cold ESP, which may remove more than 95 percent of the total particulate matter present in the gas. Control of SO_2 emissions from smelter sources is most commonly performed in a single or double contact sulfuric acid plant. Typically, single contact acid plants achieve 92.5 to 98 percent conversion of SO_2 to sulfuric acid, with approximately 2,000 ppm of SO_2 remaining in the off-gas. Double contact plants collect 98 to more than 99 percent of the sulfur dioxide and emit about 500 ppm of SO_2.

Ferrous Metals Processing

Smelting exhaust is primarily comprised of particulate matter which is controlled with cyclone cleaners followed by a dry or wet ESP, high pressure wet scrubber, or baghouse. Electric arc furnaces emit particulate matter in the form of fumes, accounting for an estimated 94 percent of the particulate matter emissions in the ferrous metals industry. Depending on the type of furnace in use (submerged, open, or covered), large amounts of carbon monoxide and organic materials may also be emitted. In general, baghouses are the most commonly applied control device followed by wet scrubbers and then wet and dry ESPs. Efficiencies for well designed and operated control systems have been reported to be in excess of 99 percent.

Elemental Phosphorus Processing

Scrubbers are the most common control equipment used for phosphate rock dryers and calciners, but some ESPs are also used. Control efficiencies are between 80 to 99 percent for particles between 1 to 10 micron in diameter and 10 to 80 percent for particles less than 1 micron in diameter. Fabric filters are commonly used to control particulate matter emissions from the grinders. In most operations, conveyor systems are enclosed to reduce fugitive emissions.

Lead Processing

Emission controls at lead smelters are installed for removal of particulate matter and sulfur dioxide. The most commonly used high efficiency particulate control devices are fabric filters and ESPs, which often follow centrifugal collectors and tubular coolers. Nearly identical to copper processing, lead smelters use either single or double absorption sulfuric acid plants to control SO_2 emissions from sinter machines and, occasionally, from blast furnaces.

Phosphoric Acid Processing

Gaseous fluorides generated during the wet process are routed to scrubbers prior to release to the atmosphere. However, significant fluorine emissions often occur from the phosphogypsum settling ponds and from reactor slurry cooling operations. Particulate matter from process equipment and filters is usually removed with centrifugal collectors, scrubbers, or ESPs.

In the thermal process, economical operation demands that the potential loss of product (phosphoric acid mist) be controlled; therefore, all plants are equipped with some type of control device. Control equipment commonly used in the thermal process includes venturi scrubbers, cyclonic separators with wire mesh mist eliminators, fiber mist eliminators, high energy wire mesh contractors, and ESPs. Capture efficiencies are between 95 and 99.9 percent.

The predominant emissions control measures for metal ore processing are the traditional end-of-pipe add-on control systems such as those described above. Increasingly, industry and regulatory agencies are searching for alternate measures that can be implemented to reduce the amount of emissions generated or the volume of emission streams. These alternative control measures or pollution prevention activities are frequently effective in reducing fugitive emissions, but in some cases the principal emission streams can also be reduced by fine tuning process controls and other changes in operating practices.

In smelting operations and in alumina processing, well designed hood systems can sometimes capture large amounts of off-gas fumes that would otherwise be emitted as fugitive releases. In general, few of these alternative control measures have been applied in industry. In some applications, computerized control of raw material feed rates and mixtures of raw materials within the process equipment can reduce emissions by optimizing the generation of the product.

POTENTIAL IMPACTS ON SOILS

Extraction-Surface and Underground Mining

<u>Potential Impacts</u>: The impacts to soils associated with surface and underground mining include erosion and contamination from leaching solutions. Soil erosion can be caused by surface disturbances associated with pit operations (such as access roads) or with underground operations (such as mine portals) and by runoff associated with the discharges of mine water. When mine water, runoff, and drainage from waste rock (and tailings piles) come in contact with soils, toxic metals in these waste streams can be transferred to the soils. These metals can be present both in dissolved and suspended (particulate) forms. Common contaminants include heavy metals (cadmium, lead, etc.), arsenic, and radionuclides. Contact of ARD with soils can lower both the pH and the cation exchange capacity of the soils.

<u>Mitigation Measures</u>:

- Runon and runoff control measures, such as berms and ditches.
- Treatment of wastewater prior to discharge, by (e.g.) lime neutralization or the use of natural or artificial wetlands.
- Backfilling mine workings with waste rock; reclamation and closure of portals and roads; revegetation with native species.

Beneficiation-Gold Heap Leaching and Copper Dump Leaching

Potential Impacts: The most serious impact to soils associated with heap and dump leaching is toxic pollutant contamination. Spent ore piles or dumps, if not adequately reclaimed, may cause soil contamination with heavy metals, arsenic, and other toxic constituents. Contaminated soil may be an exposure route to humans via direct contact or ingestion. Further, contamination may decrease soil productivity. Spent cyanide solutions may be treated and land applied as a method of disposal. If the spent solution is not neutralized completely, cyanide may remain in the soil. Spills of pregnant (gold- or silver-bearing) cyanide solution commonly results in accumulation of toxic metals in the soil. In addition, dump leaching often involves the use of added chemicals such as sulfuric acid and organic solvents (used in solvent extraction/electrowinning of the pregnant solution). Spills and improper disposal of these chemicals are a common source of soil contamination.

Mitigation Measures:

- Detoxification of heaps, dumps, and any spent solutions to reduce cyanide, acidity, and metal loadings. Treatment should address the entire chemical matrix of the solution.
- Biological treatment for cyanides, nitrates, and heavy metals.
- Lining of PLS and barren solution ponds, heap leach pads, and conveyances (e.g. ditches) with clay or synthetic liners.
- Installation of leachate detection and collection systems under ponds and heaps.
- Construction of seepage ponds downgradient of ponds, heaps, and dumps.
- Recycling of process water.
- Lime neutralization or wetlands treatment of acid drainage.
- Contingency plans for sudden or catastrophic releases, including sufficient on-site inventories of cyanide and acid neutralizing agents.
- Recontouring and revegetating heaps, dumps, and waste rock piles.
- Runon and runoff control measures, such as berms and ditches.

Beneficiation-Mills and Tailings

Potential Impacts: The impacts of tailings piles on soils can include contamination by mixing, leaching, and fugitive dust. Tailings typically contain heavy metals, arsenic, and radionuclides. Unlined piles can contribute particulates directly to the underlying soil, and contaminants can be leached from the piles into the soil by groundwater or precipitation infiltration. Contaminants in tailings, if applied to the soil, can decrease soil productivity. The entrainment of wind-blown particulate matter from tailings piles can cause deposition of contaminants in soils downwind from such piles. Also, the inadvertent or deliberate use of abandoned tailings for construction fill or aggregate can result in dispersal of contamination. If uncontrolled, both fugitive and stack emissions of particulate matter from mineral beneficiation operations (crushing, grinding, milling, drying, concentrating, etc.) can cause soil contamination downwind from the operations.

Mitigation Measures:

- Runon and runoff control measures, such as berms and ditches, to minimize infiltration and leaching.
- Lining of piles with clay or synthetic liners.
- Installation of leachate detection and collection systems under piles.

- Construction of seepage ponds downgradient of piles.
- Lime neutralization or wetlands treatment of acid drainage.
- Maintenance of an anaerobic environment within tailings piles to minimize pyrite oxidation and subsequent mobilization of contaminants.
- Covering and revegetating piles to suppress wind erosion and contaminant transport.
- Use of particular collectors and dust suppression activities to reduce stack and fugitive particulate matter emissions.

Mineral Processing

<u>Potential Impacts</u>: Three primary pathways exist for soil contamination from mineral processing operations: air emissions; process and storm water discharges; and waste disposal. With respect to impacts to soils, fugitive and stack emissions of particulate matter are of primary concern, however, effects of SO_2 emissions on soils can also be severe. Several mineral processing operations (copper, iron, lead, and elemental phosphorus) generate slag which is disposed of in slag piles. Red mud, produced during alumina production, and phosphogypsum, produced during phosphoric acid production, are typically disposed of in settling ponds. Potential impacts to soils from contaminants found in these wastes are similar to those described above for tailings. Contaminants may be leached from the slag or settled wastes, storm water may become contaminated from contact with wastes, or the settling ponds could overflow during heavy precipitation events.

<u>Mitigation Measures</u>:

- Installation of effective control devices and use of BMPs to reduce fugitive and stack emissions of particulate matter, SO_2, phosphoric acid mist, or other airborne pollutants.
- Runon and runoff control measures, such as berms and ditches, to minimize infiltration and leaching from waste disposal areas.
- Lining of slag piles and settling ponds with clay or synthetic liners.
- Installation of leachate detection and collection systems under waste disposal areas.
- Construction of seepage ponds downgradient of waste disposal areas.
- Recycling or treatment of cooling pond water.

POTENTIAL ASSOCIATED ON ECOSYSTEMS

Evaluating potential environmental impacts to an ecosystem from a proposed mining operation involves a consideration of impacts to the aquatic and terrestrial components of the system. Potential effects to the individual components of the ecosystem need to be addressed. However, an analysis of the combined and cumulative impacts should also be assessed in terms of the ecosystem as a whole. The following section presents an overview of aquatic and terrestrial components of ecosystems, including potential impacts from mining activities, followed by a list of potential mitigation measures.

Aquatic Resources

For impact assessment purposes, aquatic life is generally defined as fish and benthic macroinvertebrates; however, phytoplankton and other life forms may also be considered, depending on the type of aquatic habitat and the nature of impacts being assessed. Baseline conditions of aquatic resources should be described using surveys of fish and macroinvertebrates/benthic organisms. These surveys should be designed to adequately describe seasonal variation to be expected within the watershed. A detailed discussion of the many approaches and methodologies that may be used to define and monitor aquatic resources is beyond the scope of this document.

Changes in water quality result in impacts on aquatic resources that typically occur in two forms: the addition of sediment or toxic/hazardous materials (metals) to streams and water bodies; and, the direct disruption of ephemeral, intermittent, or perennial streams; wetlands; or other water bodies. Impacts may result in changes to relative abundance or biological diversity. Impacts to aquatic resources can be evaluated using the 1989 EPA document, *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* (EPA, 1989).

Terrestrial Resources

The major components of terrestrial resources include vegetation and wildlife. The distribution of vegetation is dependant on the local climatic regime, soils, slope, and aspect. Vegetation is typically described in terms of communities or associations -- based on the dominant species of the particular community. Native plant communities perform a number of functions in the landscape. Vegetation stabilizes the soil surface, holding soil in place and trapping sediment that may otherwise become mobilized; it also functions to modify microclimatic conditions, retaining soil moisture and lowering surface temperatures. A diverse landscape also provides some degree of aesthetic value. The density and type of wildlife species present within a site depends largely on the native vegetation communities. Local experts from state and Federal agencies should be consulted to identify which plant and wildlife species of concern are potentially located within the affected area. These specialists are also able to provide information on the types of communities in which particular species are likely to be found. In some instances, it may be desirable to focus on certain local species of concern; however, it is usually preferable to assess impacts on the overall ecosystem.

Impacts to vegetation are primarily associated with the land-clearing activities conducted in advance of mining operations. Baseline data for vegetation should include a description of the major plant communities or associations within the affected area. The description of each community should include the percent of vegetation cover, a measure of productivity (biomass production), a measure of plant species diversity, and a qualitative description of the dominant species. The extent of disturbance within each community should also be identified.

Impacts to wildlife include habitat loss, degradation, and alteration associated with the destruction of vegetation. Noise during the construction phase or operations may result in the displacement of wildlife populations from otherwise undisturbed areas surrounding the site. Some individuals or species may rapidly acclimate to such disturbances and return while others may return during less disruptive operational activities. Still other individuals may be permanently displaced for the life of the project. Exposure to toxic/hazardous chemicals through solution ponds, tailings impoundments or spills pose a threat to individuals. The duration and extent of impacts are important considerations for wildlife. The U.S. Fish and Wildlife Service (USFWS) Habitat Evaluation Procedure (HEP) measures the quality of habitat as it relates to certain species. Habitat loss may be temporary (e.g., construction-related impacts), long-term (e.g., over the life of a mine), or essentially permanent (e.g., the replacement of forested areas with waste rock piles).

Assessment/prediction of potential wildlife impacts requires an accurate description of baseline conditions as well as a long-term monitoring program to identify any changes from the pre-disturbance environment. Wherever possible, quantitative assessments of wildlife populations and their habitat are always preferred. Quantitative assessment of impacts often includes comparison of pre- and post-impact species populations. This typically requires field surveys of local populations. Impacts to terrestrial resources can be evaluated using the 1993 EPA document, *Habitat Evaluation: Guidance for the Review of Environmental Impact Assessment Documents.* (EPA, 1993).

Riparian/Wetlands

Native vegetation communities can often be broken down into upland and lowland types. Upland communities consist of forests, shrublands and grasslands. Lowland vegetation occurring within drainages forms riparian (streamside) communities, including wetlands. Wetlands and riparian areas are usually the most productive and diverse vegetation types within an ecosystem. As such, these vegetation types are subject to additional regulatory requirements including §404 of the Clean Water Act, Executive Order (EO) 11988 (Floodplain Management), and EO 11990 (Protection of Wetlands). The following discussion addresses the unique concerns associated with these lowland vegetation types.

Riparian communities and wetlands provide functions within the landscape as defined in Wetland Evaluation Technique (WET) Volume II: Methodology (Adamus et al., 1987): (1) groundwater recharge; (2) floodflow attenuation; (3) sediment stabilization; (4) sediment/toxicant retention; (5) nutrient removal/ transformation; (6) primary production export; (7) wildlife diversity/abundance; (8) recreation; and (9) uniqueness and heritage. Baseline data should include an evaluation of the functions provided by each wetland within the project area and a measure of its areal extent.

The requirements for defining and mitigating impacts to wetlands are more rigorous than other vegetation community types because of their protection under §404 of the Clean Water Act (see Chapter I). The placement of dredged or fill materials into wetlands or other waters of the U.S. requires that a §404 permit be obtained from the U.S. Army Corps of Engineers. Delineations are conducted as described in the Corps of Engineers Wetlands Delineation Manual (USACE, 1987), and are based on an assessment of vegetative, hydrologic, and soils criteria. If jurisdictional wetlands are identified, the project must comply with the §404(b)(1) guidelines (40 CFR Part 230).

Impacts to wetlands may occur directly or indirectly. Direct impacts could include removal for development of a pit or filling as a result of construction of a tailings impoundment. Sediment accumulation may impact wetlands on-site or downstream from the project area.

<u>Mitigation Measures</u>:

NEPA documentation for proposed mining activities should include mitigation measures which may or will be used to minimize or avoid impacts to aquatic resources, vegetation, and wildlife. Potential mitigation measures for use at mine sites include:

- Employ sediment retention structures to minimize the amount of sediment migrating off-site.
- Employ an effective spill prevention and control plan to minimize the discharge of toxic/hazardous materials into water bodies.
- Site roads, facilities and structures to minimize the extent of physical disturbance.
- Conduct temporary and permanent reclamation contemporaneously such that stockpiles, waste dumps, and roads not in use can be stabilized or moving toward final reclamation.
- Avoid construction or new disturbance during critical life stages. For example, delay construction activities until after sage grouse strutting occurs at nearby leks.
- Reduce the chance of cyanide poisoning of waterfowl and other wildlife, particularly in arid environments, by neutralizing cyanide in tailings ponds or by installing fences and netting to keep wildlife out of ponds. Explosive devices, radios, and other scare tactics have generally not been proven effective.
- Minimize use of fences or other such obstacles in big game migration corridors. If fences are necessary, use tunnels, gates, or ramps to allow passage of these animals.
- Utilize “raptor proof” designs on power poles to prevent electrocution of raptors. For example, use anti-perching devices to discourage birds from perching or nesting on poles, or place conductors far enough apart to ensure both wings don't contact them at the same time.
- To minimize the number of animals killed on mine-related roadways, use buses to transport employees to and from the mine from an outer parking area.
- To limit impacts from habitat fragmentation, minimize the number of access roads and close and restore roads no longer in use.
- Prohibit use of firearms on site to minimize poaching.

SUMMARY OF QUESTIONS THAT SHOULD BE ASKED WHEN REVIEWING NEPA DOCUMENTATION

The following are questions that may be appropriate to ask about mining operations when reviewing NEPA documentation:

General Questions Applicable to Most Mining Operations

- Has the local geology been defined, including all stratigraphic layers to be encountered in mining?

- Has baseline data been collected to establish the surface water flow rates (including seasonal variability) and water quality (including sediments) prior to disturbance? Has the physical condition of streams within the project area been determined? Has aquatic life been adequately characterized? What are the designated and actual uses of surface water in the project area and downstream?

- What is the overall water balance for the facility? Have all potential discharges to groundwater and surface water been anticipated and described (and controls provided, as appropriate)? Does the applicant intend to obtain all necessary NPDES permits? Can the facility ensure compliance with applicable water quality standards?

- Has the hydrogeology of the site been mapped/clearly delineated? Has baseline groundwater quality been determined? What are the designated and actual uses of groundwater? What are the locations of all wells in the area and what are their uses?

- Has the erosion potential been quantified? Have the appropriate runoff models been used? Are the assumptions defined and justified? Have the potential impacts on surface water been determined? Wherever possible, has model data been validated by comparison to actual field data? What runon and runoff control measures, including BMPs, will be used? Will they be maintained during active operations and afterward?

- Have baseline studies been conducted to characterize aquatic and terrestrial life/habitats prior to mining/disturbance? Are there any threatened, endangered, or rare species and/or critical habitats in the area? Have the requirements of the Endangered Species Act been followed? What measures will be taken to protect wildlife/habitat, including siting?

- Will any disturbance impact wetlands? If yes, what mitigation measures will be taken? If jurisdictional wetlands are impacted, have CWA §404(b) requirements been followed?

- Are the cumulative impacts over the life of the mine (including possible expansions) described?

- Is public access to the site controlled? Is wildlife access to the site controlled? Is the control described?

- Have the pre- and post-mining land uses been compared?

- What wastes will be generated? In what volumes? What are the expected compositions of waste materials? What management practices will be used? Do waste/materials management units have liners? Will adequate surface preparation be performed prior to liner installation? Do units have drainage collection systems? Leak detection systems?

- Have leachability tests been performed on wastes (for metals, sulfates, and other potential pollutants)? Have radionuclide levels been determined, (where appropriate)?

If there is sulfide mineralization, has ARD/AMD testing been conducted? Is there a plan to continue waste characterization/acid generation testing during operations?

- Where wastes can generate ARD, what measures will be used to minimize acid generation and/or provide treatment prior to discharge? Are mitigation measures for ARD/AMD based on proven technologies (e.g., conventional treatment), state-of-the-art technologies, or passive treatment practices (e.g., wetlands)? If unproven methods are to be used, how will performance be monitored and have contingencies been provided for?

- Is there a multi-media monitoring program (including surface and groundwater, sediments, and air)? Are proposed parameters representative of likely discharges? Where and how often will monitoring occur? Do monitoring frequencies account for seasonal/operational variability? If impacts are detected, what actions will be taken? How and to whom will data be reported?

- Is there a spill prevention and response plan? Does it address all areas where spills are likely to occur? Is secondary containment provided for storage areas and pipelines?

- Is there a reclamation/closure plan? Will concurrent reclamation be performed? Have proposed revegetation procedures been successfully used in the area previously? Has long-term mine water management been addressed? After closure, will drainage systems/discharges continue to be monitored/maintained/addressed?

- Has the baseline air quality been determined? How will air emissions be minimized? Have stack and fugitive emissions been characterized/predicted/modelled? What technologies will be used to control such emissions? How will any air pollution control wastes be managed? Does the project plan ensure compliance with Federal and State CAA requirements? Has the baseline meteorology for the area been adequately characterized and data made available?

Mine Workings

- Is groundwater pumped to control water inflow into the mine workings/pit? At what rate is the water pumped? Have the extent of aquifer drawdown and the subsequent impacts been described?

- Are all aquifers and surface waters that might be impacted identified and included in a monitoring plan? Are groundwater discharge areas (wetlands, ponds, lakes, streams, seeps, etc.) included in a monitoring plan? Does the monitoring plan account for seasonal variances? If an impact is suspected, what responses are proposed?

- What are the consequences when mining and water withdrawal cease and the pit/mine workings are subsequently flooded? What action will be taken once mining stops and pumping is no longer employed to dewater the workings?

- Have the characteristics of the mine water been determined, including AMD? Will collection and treatment be provided, as appropriate?

Waste Rock/Overburden

- How much overburden, waste rock, and ore will be excavated and stored or disposed of? Are planned management units described fully?

- Have leaching characteristics of waste rock/overburden been determined (including ARD)? How often during mining will leaching characteristics be evaluated? What measures are proposed to ensure protection of groundwater and surface water from constituents leaching from waste rock dumps or overburden piles?

- Has the stability of waste management units/impoundments been determined? Did the analysis consider any seismic risk? Will adequate drainage of berms be provided? How will stability be measured during and after active operations?

- Is closure and reclamation of these waste rock/overburden described in detail? Is recontouring of the piles to stable slopes required? Will concurrent reclamation be conducted, if appropriate?

Tailings Impoundments

- What are the constituents in the tailings? What type of sampling was conducted and was it representative? Have leaching characteristics of tailings been determined? If so, what methods were employed? How often will sampling and characterization be conducted during operation? Have reagents used during beneficiation been addressed in the constituent analysis? What measures are proposed to ensure protection of groundwater from constituents leaching from tailings impoundments?

- What other wastes does the operator dispose of in the tailings pond or tailings area? How are these materials managed as wastes?

- Does the project plan provide for maximum possible water reclaim/re-use? Have all potential source reduction/recycling opportunities been identified and reviewed?

- Has adequate precipitation and snow melt data been compiled? Have all collection/containment and treatment systems been properly designed to manage up to a specific storm event and snow melt contributions (i.e., are they appropriate for the predicted water balance)?

- What analysis was conducted to determine stability of any structures (i.e., dams or berms) associated with the tailings pile or pond? Did the analysis consider snow melt contributions? Did the analysis consider seismic risk? Does the document contain detailed drawings so that structural stability can be determined? Have runon, runoff and unit capacity been evaluated? Have these evaluations considered storm water and annual snow melt?

- Does the plan provide for maximum recycling/reuse of pond water? Is there a surface water discharge? What are the expected flow rates and discharge characteristics? Has adequate treatment been provided, if necessary?

- Is the closure and reclamation of the tailings ponds described in detail? What steps constitute closure? Is recontouring of the pond required? Is a cap proposed?

Copper Dump Leach Operations and SX/EW Plants

- What is the planned design of the dumps? How much material will be leached? How will solution be applied? Has the stability of been determined? How will stability be measured during and after active operations?

- What are the characteristics of dump materials, including ARD potential? What type of sampling/testing was conducted and was it representative? What analytical method was used to determine the constituents and what were the results? Are there any other wastes generated (e.g., bleed streams)? What are their characteristics and how will they be managed?

- Is the leaching process a closed loop system (e.g., is all solution collected)? What will the water balance be after leaching ceases? Have the capacities of the solution transport ditches and collection ponds been evaluated considering process solutions and runoff/snow melt contributions? Are solution ditches and ponds lined/double-lined? Is there a leak detection/collection system?

- How will reagents be transported/stored? Is there secondary containment/leak detection? Is there a spill prevention and response plan?

- How will the dump affect ground and surface water quality during leaching operations and after closure? Will monitoring be performed? Where, when, and for which parameters?

- Will the dump be operated on a seasonal basis? Are temporary closure procedures proposed? Will the dump be monitored on a regular basis during the inactive season?

- What is the proposed closure/reclamation plan? Will concurrent reclamation be conducted, if appropriate?

Cyanide Leaching Operations

- Are the heap leach pad and process ponds lined appropriately? Is a leak detection system in place and operational? Is an adequate monitoring plan proposed? What triggers (chemical constituents) are to be employed within the monitoring plan to signify the possibility of a leak? What are the proposed contingency plans in the event a leak is detected?

- Has the stability of heaps/spent ore management units/impoundments been determined? Did the analysis consider any seismic risk? How will stability be measured during and after active operations?

- Has adequate precipitation and snow melt data been compiled? Have all collection/containment and treatment systems been properly designed to manage up to a specific storm event and snow melt contributions (i.e., are they appropriate for the predicted water balance)?

- Are the closure of heaps described in detail? What is the closure treatment method? What "standard" will be used to measure successful closure? Do spent heaps present risks after closure, including ARD potential?

- Will the heap be operated on a seasonal basis? Are temporary closure procedures proposed? Will the heap be monitored on a regular basis during the inactive season?

- Will concurrent reclamation be conducted, if appropriate?

- How will reagents be transported/stored? What measures will be taken to prevent spills? Is there a spill prevention and control plan being developed?

- What measures will be used to limit human and wildlife access to the leaching operation?

***In Situ* Mining**

- What are the proposed lixiviants? Is there demonstration as to the integrity of the target aquifer? Are injection and recovery rates sufficient to maintain a cone of depression within the target aquifer? Are monitoring plans developed to detect constituents of the lixiviant or an appropriate byproduct? What are the contingency plans in the event of an excursion? What methods are proposed for aquifer restoration?

- Have waste streams been identified? What are the expected compositions of waste materials? How are the end products of each waste stream managed? Have radionuclide levels been determined, (where appropriate)?

- Are solution ditches and ponds lined? Is there leak detection? Is there a plan to address spills and leaks?

Milling Operations

- What types of beneficiation will be used at the mill? What are the waste streams associated with these operations? What are the constituents of each waste stream? What type of sampling was conducted to provide the description and was it representative? Were the waste streams tested using the Toxicity Characteristic Leaching Procedure (TCLP) or other test method? What were the results?

- How will air emissions be minimized? What technologies will be implemented for fugitive dust emission control? What performance standards were described for these technologies? How will air pollution control dust be managed? If air pollution control dust will be reused, in what process will it be reused?

- How will waste streams be managed? Will on-site ponds be used? Will water be recycled back to the process?

- Is closure and reclamation of the mill and surrounding area described in detail? Will the mill be disassembled after the operation is closed? Is the closure and reclamation proposed for the site described in detail?

- How will reagents be transported/stored? Is there secondary containment? Is there a plan to prevent/address spills or leaks of reagents, products, and wastes?

Smelting/Refining Operations

- What are the waste streams associated with the smelter or refining operation? What are the constituents of each waste stream? What type of sampling was conducted? Was it representative? Were the waste streams tested using the TCLP or other test method? What were the results?

- How will waste water streams be treated and/or managed? Will on-site ponds be used? If so, will they be lined? Will the water be recycled back to the process?

- How will slag from the smelting furnace be managed? Will any be recycled back to the concentrator?

- How will emissions be minimized? What technologies will be implemented for fugitive dust and gas emission control? What performance standards were described for each of these technologies? How will air pollution control dust be managed? If air pollution control dust will be reused, in what process will it be reused? How and where will air pollution control sludge be managed?

- Where and how are wastes such as bleed electrolytes, acid rinsing, tank bottoms, vessel cleanouts, used oil, etc. being disposed of? Is the facility permitted?

- For metallurgical sulfuric acid plants, how will acid blowdown be handled? What are the characteristics of the acid plant blowdown (constituent concentrations, etc.)?

Phosphoric Acid Production/Phosphogypstacks

- What is the specific manufacturing process used at the site? What is the water balance for the facility? What are the current and planned dimensions for the phosphogypstack and cooling ponds?

- What is the pH and chemical composition (phosphorous, sulfur, fluoride, radionuclides, metals, etc.) of the phosphogypsum and process wastewaters/cooling pond waters? If a leaching test was performed on the phosphogypsum, how was it performed? Because leachate is expected to have an extremely low pH (<1), a standard Toxicity Characteristic Leaching Procedure (TCLP) will likely underestimate leaching potential.

- What other wastes/wastewaters does the operator dispose of in the stacks and/or cooling ponds?

- What is the capacity of the drainage system? Does it take local climatic factors into consideration? Is overflow anticipated? If yes, how will it be managed?

- Was an analysis conducted to determine the structural stability of the phosphogypstacks? Has the analysis been certified by a professional engineer (PE)? If applicable, did the analysis consider snow loading? Does the documentation include drawings to verify the structural stability?

- What measures will be used to limit public and wildlife access to the phosphogypstacks?

- Is there a closure plan for the phosphogypstacks? How long will be required for the stack to fully drain? Will environmental monitoring continue after closure as long as the potential for impacts remain?

CHAPTER IV

SPECIFIC ENVIRONMENTAL CONCERNS

The potential impacts associated with mining range from short-term (on the order of years) to long-term (essentially in perpetuity). This chapter describes several of the potentially major impacts which, if they occur, have long-term implications. They include:

- Acid Drainage
- Releases from Cyanide Leaching Operations
- Sedimentation/Erosion
- Aquifer Drawdown

ACID DRAINAGE

The formation of acid drainage and the contaminants associated with it has been described as the most serious environmental problem facing the U.S. mining industry (U.S. Forest Service, 1993; Ferguson and Erickson, 1988; Lapakko, 1993b). Commonly referred to as acid rock drainage (ARD) or acid mine drainage (AMD), acid drainage from mine waste rock, tailings, and mine structures such as pits and underground workings is primarily a function of the mineralogy of the rock material and the availability of water and oxygen. While acid may be neutralized by the receiving water, dissolved metals can remain in solution. Dissolved metals in acid drainage may include the full suite of heavy metals, including lead, copper, silver, manganese, cadmium, iron, and zinc.

Acid is generated at mine sites when metal sulfide minerals are oxidized. Primary factors in acid generation include sulfide minerals, water, oxygen, ferric iron, bacteria to catalyze the oxidation reaction, and generated heat. Neutralization can occur from the alkalinity released when acid reacts with carbonate minerals in waste/host rock. The most common neutralizing minerals are calcite and dolomite. Additional factors of importance to acid generation include the physical nature of a waste/material, such as particle size, permeability, and physical weathering characteristics.

Acid generation prediction tests are relied upon increasingly to assess the long-term potential of a material or waste to generate acid. Because mineralogy and other factors affecting the potential for ARD formation are highly variable from site to site, predicting the potential for ARD is currently difficult, costly, and of questionable reliability. Further, concern has developed because of the lag time at existing mines between waste emplacement and observation of an acid drainage problem (University of California, Berkeley, 1988). With acid generation, there is no general method to predict its long-term duration (in some cases necessitating perpetual care). Regardless of the method selected, the individual applicant's pre-project testing should be representative of each rock type, provide good spatial coverage, and be proportional to waste quantities.

There are two primary approaches to addressing ARD: (1) avoiding mining deposits with high ARD potential (identified through upfront testing); and (2) implementing mitigation measures to limit potential ARD impacts. In practice, the complete avoidance of mining in areas with the potential to form ARD may be difficult due to the widespread distribution of sulfide minerals. Specific mitigation measures include:

- Use of a low permeability cover to isolate water (and oxygen) from acid forming materials.

- Segregation of materials to minimize acid generation potential; for example, carbonate materials can be placed on the surfaces of piles, while potentially acid generating materials are placed below the surface.

- Blending of alkaline materials with acid forming materials within waste disposal units.

- Hydrologic controls (e.g., drainage systems) to reduce the amount of water percolating through acid forming wastes.

- Use of bactericides (although bactericides ultimately have a limited life span).
- Placement of acid forming materials below the final potentiometric surface (ensuring sufficient water depth).
- Collection and treatment of drainage using neutralization/precipitation, anoxic limestone drains (ALDs), wetlands, or sulfate reducing bacteria.

For the most part, only limited data are available to document the long-term effectiveness of any of these controls. Further, individual site conditions significantly impact their feasibility and performance in the field. In many cases, the measures described above are most effective when used in combination and adapted to the situation at a specific site.

RELEASES FROM CYANIDE LEACHING OPERATIONS

A substantial proportion of the sodium cyanide produced in the U.S. is now used by the mining industry; over 100 million pounds were used by gold/silver leaching operations (both tank and heap leaching) in 1990, less than 5 million pounds for copper/molybdenum flotation, and much less than 5 million pounds in lead/zinc flotation. The acute toxicity of cyanide, and a number of major incidents, have focused attention on the use of cyanide in the mining industry.

In general, cyanide can cause three significant types of potential environmental impacts: (1) cyanide-containing ponds and ditches can present an acute hazard to wildlife and birds; (2) spills can result in cyanide reaching surface water or groundwater and causing short-term (e.g., fish kills) or long-term (e.g., contamination of drinking water) impacts; and (3) cyanide in active heaps and ponds and in mining wastes may be released and present hazards to surface water or groundwater, and there may be geochemical changes that affect the mobility of heavy metals. These impacts and the major issues and uncertainties associated with each are described briefly below.

The heightened awareness of the threat to wildlife and birds presented by cyanide-containing ponds and wastes have led to steps to reduce/eliminate access to cyanide solutions or to reduce cyanide concentrations in exposed materials to below lethal levels. Operators can reduce access in several ways, including covering solution ponds with netting or covers, using cannons and other hazing devices (e.g., decoy owls) to scare off waterfowl and other wildlife, and/or installing fencing to preclude access by large wildlife. At least one mine uses tanks to contain all solutions. In addition, operators may elect to treat tailings slurries to reduce cyanide concentrations, maintain higher fluid levels in impoundments to dilute concentrations, or reduce the amount of free liquids in impoundments to minimize pond surface area.

Most actual environmental impacts resulting from cyanide releases have been associated with spills and major failures of containment structures. Heap leach operations use liner systems of various types under heaps and solution ponds, which may have seepage collection/detection systems to control leaks. The type of liner system that is used generally is based on site conditions, operator preference, and regulatory requirements (Van Zyl, 1991). Liners are usually made of polyvinyl chloride (PVC) or high density polyethylene (HDPE); recently, very low density polyethylene (VLDPE) liners have been developed. In many cases where there have been significant liner failures, they have been due to improper installation/inadequate construction QA/QC.

In general, cyanide is not believed to present a significant problem over the long term, particularly if the obstacles to detoxification and reclamation are overcome. As noted above, however, there are many complexities associated with detoxification and reclamation; whether difficulties will be encountered is seldom known at the time that the potential environmental impacts of a mining operation are evaluated. As a result, environmental documentation should describe contingency plans for overcoming possible difficulties and potential impacts under these conditions.

If detoxification is successful, most residual cyanide in closed heaps and impoundments will be strongly complexed with iron. Although the stability of such complexes over long periods is not well understood, cyanide is generally considered to be much less a long-term problem than acid generation, metals mobility, and stability. Thus, evaluating the potential post-operational environmental impacts associated with cyanide in heaps, spent ore dumps, and tailings involves assessing the means by which operators ensure that cyanide and its breakdown products and metallic complexes are contained and reduced to environmentally benign levels prior to site abandonment. Conceptual plans for operators who will detoxify and reclaim heaps and tailings are generally available at the time environmental impact assessments are performed, but the details are not. Plans should describe not only what is anticipated to occur at closure and reclamation (e.g., continued recycling of rinse water until WAD cyanide levels reach regulatory standards) but also the environmental implications of potential difficulties and changes in plans.

SEDIMENTATION/EROSION

Because of the large area of land that is disturbed by mining operations and the large quantities of earthen materials exposed at sites, erosion is frequently a primary concern at hardrock mining sites. Erosion may cause significant loadings of sediments (and any entrained chemical pollutants) to nearby streams, especially during severe storm events, as well as high snow melt periods.

Major sources of erosion/sediment loadings at mining sites can include:

- Open pit areas
- Heap and dump leaches
- Waste rock and overburden piles
- Tailings piles
- Reclamation areas
- Ore stockpiles
- Vehicle and equipment maintenance areas
- Exploration areas
- Haul roads and access roads

The variability in natural site conditions (e.g., geology, vegetation, topography, climate, and proximity to surface waters) combined with significant differences in the quantities and characteristics of exposed materials at mines preclude any generalization regarding the quantities and characteristics of sediment loadings. Further, new sources are frequently located in areas with other active operations as well as historic mines (left in an unreclaimed state). Therefore, in considering the erosion effects from a mining source, the cumulative impacts of sediment loadings from all sources within a watershed must be considered.

The main factors influencing erosion include:

- Rainfall/snow melt runoff
- Infiltration
- Soil texture and structure
- Vegetative cover
- Slope length
- Erosion control practices in place

Impacts associated with erosion/runoff from disturbed areas include particulate matter, which is toxic to fish; contaminated sediments, which may pose long-term risks to human health and the environment; and organic-laden solids, which have the effect of reducing dissolved oxygen concentrations. Beyond the potential for pollutant impacts on human and aquatic life, there are physical impacts associated with the increased runoff velocities and volumes from newly disturbed land.

A characterization of background conditions within a potentially affected water body such as a stream is necessary to assess the potential impacts of new erosion/sedimentation sources. Important elements in assessing background conditions are evaluations of the physical parameters and habitat of a stream. There are currently several approaches/models available to assist in the prediction of sediment losses and flow responses of basins both before and after landscape alterations due to mining and other human activities. As with any models, they are highly sensitive to the input data supplied and caution must be used in identifying and quantifying the important factors for a specific project.

Sediment and erosion mitigation measures are used to reduce the amount of material carried off site and deposited in a receiving stream. To meet this objective, mine operators should consider methods to limit runon, minimize the areas of disturbed soil, reduce runoff velocity, and remove sediment from on-site runoff before it leaves the site. In many cases, a range of different BMPs/sediment and erosion controls are used concurrently at mine sites. The three main categories of sediment and erosion controls are diversion techniques, stabilization practices, and structural controls. Diversion techniques are measures that prevent runon, precipitation, and other flows from crossing areas where there is a risk of significant erosion. Stabilization refers to covering or maintaining an existing cover over soils. The cover may be vegetation, such as grass, trees, vines, or shrubs. Stabilization measures can also include nonvegetative controls such as geotextiles (matting, netting or blankets), mulches, riprap, gabions (wire mesh boxes filled with rock), and retaining walls. Finally, structural controls involve the installation of devices to store flow or limit runoff velocity. Some examples of structural practices include settling ponds/detention basins, check dams, rock outlet protection, level spreaders, gradient terraces, straw bale barriers, silt fences, gravel or stone filter berms, brush barriers, sediment traps, grass swales, pipe slope drains, earth dikes, and other controls such as entrance stabilization, waterway crossings or wind breaks.

In some cases, the elimination of a pollution source through capping sources of erosion may be the most cost effective control measure for sediment discharges and other pollutants. Depending on the type of management practices chosen, the cost to eliminate the pollutant source may be very high. Once completed, however, maintenance costs will range from low to none.

AQUIFER DRAWDOWN

Aquifer drawdown and associated impacts to surface waters and adjacent wetlands can be a serious and long-lasting problem, especially in areas where mining and subsequent pumping operations are concentrated (e.g., the Carlin Trend). Several mines in the Carlin Trend have continuous pumping rates of 70,000 gallons/minute which could result in impacts to thousands of acres of riparian habitat. Impacts from aquifer drawdown may include reduction or elimination of surface water flows; degradation of surface water quality and beneficial uses; degradation of habitat (not only in riparian zones, springs, and other wetland habitats, but also upland habitats as groundwater levels drop below the deep root zone); reduced or eliminated production in domestic supply wells; and erosion, sedimentation, and other water quality/quantity problems associated with discharge of pumped groundwater back into surface waters downstream from the dewatered area.

Impacts can last for many decades. While dewatering is occurring, discharge of the pumped water can often be used to mitigate adverse effects on surface waters. However, when dewatering ceases, the cones of depression, which may take many decades to recharge, may continue to reduce surface water flows in nearby rivers and tributaries. Mitigation measures that rely on the use of pumped water to create wetlands, for example, last only as long as the dewatering occurs.

CHAPTER V

ENVIRONMENTAL MONITORING

SURFACE WATER

Surface water monitoring should include both discharge and instream water quality sampling. Instream monitoring should address both the water column and sediments. Parameters such as flow rate and temperature typically are measured either continuously or instantaneously. Monitoring for other parameters, including metals, TSS, etc., is performed by collecting grab or composite samples. The likely characteristics of discharges should be described in NEPA documentation and provide the basis for selection of monitoring parameters. Where a wide range of pollutants (that may have cumulative toxic affects) or a particular pollutant (known to be toxic) are expected to be present, whole effluent toxicity (WET) testing is often appropriate. Determination of whether to measure dissolved or total pollutant concentrations is generally based on the nature of the applicable water quality standards.

Instream water quality monitoring should be performed immediately downstream of pollutant sources (including controlled and uncontrolled discharges and potentially contaminated seeps/groundwater recharge). Baseline data should be collected prior to disturbance. Reviewers should be aware that, unlike many other types of industrial operations and discharges, there can be extreme variability in pollutant loadings from mining operations, both from day to day and over months and years. Further, the receiving water may be particularly sensitive to loadings of toxic pollutants during specific periods (e.g., under certain flow conditions). In performing baseline analyses, the operator should ensure that these conditions are identified (as well as determining background concentrations). The discharge and surface water sampling program should then be tailored to include sampling and analysis during these critical periods.

GROUNDWATER

Siting of groundwater monitoring wells requires a characterization of the baseline groundwater resources in the project area, including descriptions of aquifers (bedrock and alluvial), aquifer characteristics, and the flow regime/direction for each aquifer. The influences of bedrock fracturing should also be mapped/determined. This information can then be used, along with the locations of potential contaminant sources, to install upgradient and downgradient monitoring wells. Detection wells should be sited immediately downgradient of pollutant sources. NEPA documentation should describe the location, depth, construction/completion data, and sampling and analytical methods for all wells. Monitoring parameters should be selected based on the nature of contaminant sources. Indicator parameters such as pH, sulfate, specific conductance, and dissolved solids often provide an early indication that releases are occurring. In general, two years of background monitoring data are necessary to establish a baseline for all parameters. Further, upgradient monitoring should continue during operations to detect any changes in baseline conditions.

To detect releases, mean downgradient parameter values are typically compared to upgradient/baseline values to detect statistically significant differences in groundwater quality. A wide range of statistical procedures may be used for such comparisons. After a release has been detected, more frequent monitoring, analyses for additional parameters, and/or installation and sampling of new wells may be necessary to fully characterize the extent of releases.

AIR

Monitoring for air pollutants from industrial operations typically is performed at the exit points of stacks, process vents, etc. Air monitoring locations for more dispersed operations, such as surface mining, may be performed at reasonable alternative locations, such as the facility boundary, and may involve comparison of upwind and downwind sampling results. Selection of monitoring locations requires an understanding of site-specific meteorological conditions that can affect pollutant fate and transport. Monitoring may be either continuous or by grab or composite samples. Continuous monitoring of stack and vent effluents usually is performed for such parameters as oxygen and carbon monoxide concentrations, effluent gas temperature and velocity, etc. Parameters such as organics, metals, and particulates are monitored by analysis of discrete samples.

Particulates are measured at process vents by drawing a specified volume of air through a high-efficiency particulate (HEPA) filter and then weighing the filter to determine the gain in weight caused by the trapped particulates. Metals in the particulates can be determined by X-ray fluorescence, or by extracting the metals into an aqueous acid and determining the dissolved metals by inductively-coupled plasma (ICP) or atomic absorption (AA) spectrometry. Routine particulate monitoring at dispersed locations is accomplished with passive particulate filters situated downwind from the industrial operations.

SOILS

A project plan may provide for soil sampling to detect potential contamination from specific operations (e.g., to study metals emissions from stacks). Soil sampling may also be triggered by uncontrolled releases and can be used to monitor the effectiveness of corrective actions (e.g., to determine the effectiveness of spill clean-up measures). Sampling should be performed at locations where impacts are suspected (based on likely pollutant fate and transport). Since metals naturally occur in all soils, background samples for total metals must be obtained for comparison to suspected contaminated samples. Organic contaminants, and certain inorganics such as cyanide, are presumed not to be naturally occurring, and background sampling for these constituents is seldom performed unless another source of contamination is suspected.

Soil samples can be collected by a variety of methods. Surface samples usually can be obtained easily using simple hand tools such as scoops or shovels. Surface samples normally are analyzed as grab samples, although background samples usually are composited to provide average values. Subsurface samples can be obtained with an auger or a split-spoon sampler. Cores from subsurface samples typically are divided into sections according to the depth below the surface, and a composite sample is obtained from each section. In addition to chemical analyses, the physical appearance and lithology of subsurface cores also should be recorded.

Additional investigative techniques for soils (where contamination is likely), such as soil gas monitoring and cone penetrometer surveys, also may be conducted according to the suspected nature and extent of soil contamination.

WASTES

Waste stream samples can either be solids, liquids, or both, and also may contain immiscible organic phases. The wide variety of waste sample matrices and constituents makes generalization of sampling techniques difficult. Any of the sampling and analytical techniques discussed previously for other sample types may be applicable to waste samples. At mine sites, selection of parameters should be based on the local geology as well as potential contamination originating from site operations (cyanide from leaching, mill reagents, etc.). Standardized leaching procedures such as the Toxicity Characteristic Leaching Procedure and ASTM methods can be used to predict metals mobility from waste matrices.

Of particular concern at mine sites where sulfide mineralization is encountered is the potential for acid drainage from waste rock and tailings. Examination of the lithology of waste rock and subores may help predict the potential for acid drainage and contamination by toxic metals. If static or kinetic acid generation testing is performed, the reviewer should be aware of the significant uncertainty associated with existing test results (especially static test data).

Mining wastestreams such as tailings piles and phosphogypsum stacks can contain appreciable quantities of radionuclides. The radioactivity of a waste can be measured as total radiation of a particular type, such as gross alpha or gross beta; the activities of individual nuclides also can be determined.

CHAPTER VI

POLLUTION PREVENTION

The environmental review process provides valuable opportunities for incorporating pollution prevention into proposed mining projects during siting, design, construction, operation, and closure. The Pollution Prevention Act of 1990 establishes a national policy of pollution prevention. NEPA's very purpose is "to promote efforts which will prevent or eliminate damage to the environment..." (42 U.S.C 4321) §101 of NEPA declares a policy that the Federal government "use all practical means and measures... to create and maintain conditions under which man and nature can exist in harmony... (42 U.S.C 4331(a))." Additionally, NEPA's implementing regulations are designed with the goal of preventing or minimizing environmental degradation. These authorities provide sufficient basis for including pollution prevention opportunities into proposed design and operating alternatives. Pollution prevention can also be incorporated into mitigation measures, although it is important to recognize that the goal of pollution prevention is to avoid impacts altogether.

The formal definition of "pollution prevention" refers to source reduction and other practices that reduce or eliminate the creation of pollutants. Pollution prevention is a multi-media approach that minimizes or eliminates waste or emissions to land, air, and water without transferring pollutants from one media to another. Pollution prevention techniques include:

- Equipment or technology modifications;
- Process or procedure modifications;
- Teformulation or redesign of products;
- Dubstitution of raw materials; and,
- Improvements in housekeeping, maintenance, training, or inventory control.

While not always included in narrow definitions of pollution prevention (that focus only on source reduction), other pollution reduction/waste minimization opportunities such as recycling, procurement of recycled products, and energy recovery can also reduce the need for waste treatment and disposal, as well as conserving energy and natural resources.

There are several broad categories of actions available to mining operations that can serve to reduce pollution generation or release, whether over the short or longer terms or both. It is emphasized, however, that any examination of pollution prevention alternatives has to recognize that mining presents unique challenges that require creative approaches. These categories include:

- Specific actions that are common to any large industrial operation, related to vehicle and equipment operation and maintenance. There are many opportunities for product substitutes (e.g., solvents) and recycling (e.g., lubricating oils and grease).

- More general actions that reflect facility-wide and process-specific examinations of all operations to identify opportunities for increasing operational efficiency and conserving energy and resources. Facility-wide "pollution prevention plans" are one manifestation of these types of actions. The process of having to complete such a plan can not only improve environmental performance but may also lead to major cost savings. Perhaps equally as important, overt management attention to environmental performance and pollution prevention sends a powerful message throughout an organization, which can only be reflected in continual improvements. Similarly, plans to implement rigorous plans to ensure good housekeeping and inventory control can promise improved environmental performance.

- Specific actions to reduce the environmental "footprint." Mining operations cause massive land disturbance, often over large areas. Reducing the total amount of disturbance--by reducing the size of the site itself and/or by leaving as much undisturbed areas as possible within the site can have several benefits. Minimizing on-site disturbance and leaving "islands" of undisturbed areas, for example, can not only reduce erosion during a site's active life, but also can provide micro-habitats that speed up ultimate site reclamation and repopulation by native flora and fauna.

- Specific actions to reduce environmental releases and damages. These include site-specific design and operational measures that account for waste generation and potential releases during the active life and after. This can ensure, for example, that initial designs of waste units or plans for the long-term stability of the site take into account the ultimate configuration of the site and its characteristics (e.g., topography, hydrogeology, acid potential).

CHAPTER VII

LIST OF CONTACTS

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Others:

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CHAPTER VIII

GLOSSARY

Access Road: A route constructed to enable plant, supplies, and vehicles to reach a mine, quarry, or open pit.

Acid Mine Drainage (AMD): See Acid Drainage.

Acid Drainage: Water from pits, underground workings, waste rock and tailings containing free sulfuric acid. The formation of acid drainage is primarily due to the weathering of iron pyrites and other sulfur-containing minerals. Acid drainage can mobilize and transport heavy metals which are characteristic of metal ore deposits.

Acid Rock Drainage (ARD): See Acid Drainage.

Acid Generation Potential: A material's potential to generate acid and produce acid drainage. Analytical tests used to assess a materials' acid generation potential are either static or kinetic.

Acid Potential (AP): A common static test that estimates the maximum amount of acid that can be generated by a given material. The AP is determined by multiplying the percent of total sulfur in the sample by a scaling factor. For example, AP = 31.25 * %S. AP is typically used in conjunction with neutralization potential in various acid-base-accounting (ABA) measures.

Acid-Base-Accounting (ABA): Various methods of ABA consist of static tests that attempt to evaluate the potential for acid generation and drainage by comparing various measures of acid-forming and acid-neutralizing materials found in the mine waste or mine workings.

Adit: A horizontal or nearly horizontal passage driven from the surface for the working or dewatering of a mine. (Dictionary)

Alluvium: Clay, silt, sand, gravel, or other rock materials transported by flowing water and deposited as sorted or semi-sorted sediments in river beds, estuaries, and floor plains, on lakes, shores and in fans at the base of mountain slopes, and estuaries.

Barren Solution: A solution in hydrometallurgical treatment from which valuable constituents have been recovered. In heap and dump leaching, the barren solution is applied to the surface of the ore to dissolve metals as it percolates downward, in the process becoming “pregnant solution.”

Beneficiation: The dressing or processing of ores for the purpose of (1) regulating the size of the desired product; (2) removing unwanted constituents; and (3) improving the quality, purity, or assay grade of a desired product. For purposes of RCRA, beneficiation operations include crushing, grinding, washing, dissolution, crystallization, filtration, sorting, sizing, drying, sintering, pelletizing, briquetting, calcining to remove water and/or carbon dioxide, roasting, autoclaving and/or chlorination in preparation for leaching (except where the roasting and/or autoclaving and/or chlorination/leaching sequence produces a final or intermediate product that does not undergo further beneficiation or processing), gravity concentration, magnetic separation, electrostatic separation, flotation, ion exchange, solvent extraction, electrowinning, precipitation, amalgamation, and heap, dump, vat, tank and *in situ* leaching. In common usage, many of these beneficiation operations are referred to as “processing.”

Bond, Reclamation Bond: A performance bond whereby the operator of a mine posts some type of financial assurance that is sufficient to pay for part or all of a mine's closure/reclamation in the event that the operator does not do so.

Closure: Often used in the past as a synonym for reclamation, the term “closure” is coming to mean the process of stabilizing a mine site, both chemically and physically, prior to revegetation and other reclamation/restoration activities.

Concentration: The separation and accumulation of economic minerals from undesirable minerals.

Cyanidation: An efficient process of dissolving gold with cyanide solutions, typically sodium or potassium cyanide. Various cyanidation processes are capable of extracting gold, with up to 90 percent efficiency, in amounts as small as 0.25 percent of an ounce from a ton of rock (0.0025 oz/ton). The most common processes are carbon-in-pulp (CIP), carbon-in-leach (CIL), and heap leach/carbon-in-column (CIL). The former two are used on finely ground higher grade ores (>0.05 oz/ton). The latter uses pregnant solutions recovered from heap leaching of lower grade ores (down to ≈0.01 oz/ton).

Disseminated Ore: Ore in which the valuable mineral is more or less evenly distributed throughout the undesirable mineral as crystals or aggregates of a regular size. Because disseminated ores typically are relatively lower grades, surface mining techniques (i.e., open pits) are more often used to exploit the ore bodies, and the waste to ore ratio is much higher for such ores.

Drift: An underground horizontal passage.

Dump Leaching: A beneficiation operation most often used to extract metal values from subore-grade materials in which dilute acid, or water, is percolated through piles of low grade ore (or old waste rock or tailings). The solution is collected at the bottom of the pile, or dump, and then subjected to additional beneficiation operations to recover the metal values. Dump leaching is most commonly used in the copper industry, with copper being recovered from the pregnant leachate solutions through solvent extraction/electrowinning (SX/EW).

Electrowinning: A means of recovering metals from solution using electrochemical processes. It is usually found as a primary metal recovery activity in conjunction with acid or cyanide leaching. Pregnant leaching solution is fed into tanks where electric currents cause metal to be deposited on a cathode. During this process, the solution used in leaching is regenerated and recycled. Electrowinning is often used to recover copper, zinc, nickel, and cobalt from acid leaching operations. In the case of gold mining and beneficiation, gold is absorbed by activated carbon from cyanide leach solutions and then recovered from the carbon by chemical stripping. Electrowinning is then used to recover gold from the pregnant stripping solution.

Extraction: The process of mining: removing ores, minerals, and brines from existing geologic formations.

Flotation: A milling (beneficiation) process wherein finely ground ore (talc- to sand-sized) is introduced to a circuit where chemical reagents and/or air are introduced to concentrate the valuable minerals. The valuable minerals adhere to air bubbles and float to the top. The less valuable components (the gangue) sink to the bottom and are removed as tailings. Polymetallic sulfide ores may be subjected to two or more flotation circuits to recover different target metals.

Flux: A chemical substance used in metallurgy to react with gangue minerals to form slag which is liquid at the furnace temperatures concerned, and low enough in density to float on the molten bath or metal or matte. Examples of fluxes range in scale from large tonnages of limestone, silica, etc., in large smelting furnaces, to small quantities of borax, soda, etc., used in laboratory assay fusions.

Hard Rock Mining: Technically encompassing the mining of igneous and metamorphic rocks, the term is most often used for the mining of metal ores.

Haul Road: A road specifically built to carry heavily loaded trucks at the mine site.

Heap Leaching: A beneficiation method used to extract precious metals (gold and silver) from low grade, usually oxidized ores. Generally, crushed or run-of-mine ore is placed on an impervious surface (the "pad"), and leached over a period of time with "barren solution," usually a dilute cyanide solution. When the solution percolates through the ore, it dissolves gold (and some other metals), forming a "pregnant solution" that is collected and treated to recover the precious metals.

Industrial Minerals: Non-metallic, non-fuel minerals used in their natural state. They may require some beneficiation. Examples include: salt, sand, clay, gravel, building stone, and asbestos.

Kinetic Test: One of two major categories of tests used to predict the occurrence of acid drainage from mine wastes or mine workings (static tests comprise the other category). Kinetic tests involve repetitive cycles of leaching and monitoring under controlled conditions in the laboratory or field. Ideally, kinetic tests yield information on the extent and timing of acid generation.

Leaching: A beneficiation process wherein one or more soluble metal compounds is dissolved in a suitable solvent, such as water, or sulfuric acid, hydrochloric acid, cyanide, or other solutions. Following leaching, the valuable metal is recovered from the lixiviant solvent and the solvent is typically refortified and reused.

Leasable Minerals: Coal, oil, gas, phosphate, and certain other fuel and chemical minerals on Federal lands which can be leased under the Mineral Leasing Act of 1920, as amended, and the Mineral Leasing Act for Acquired Lands of 1947.

Lixiviant: A liquid medium used to collect minerals in solution.

Locatable Minerals: Minerals subject to location (and to claiming and development) under the general mining laws. In general, these include non-fuel metallic minerals (except uranium) and uncommon varieties of other non-fuel minerals on certain Federal lands (e.g., public domain lands open to mineral location).

Lode Deposit, Lode Mining: Traditionally, these terms meant a discrete mineral deposit that occurred between the walls of a vein, fissure, or crack in the earth's surface, and the activities associated with mining the deposit, respectively. With the advent of mining technologies that allow economic exploitation of disseminated ores, the term “lode deposit” has come to include these ore bodies and this type of mining and “lode mining” has come to mean nearly any hardrock mining for metals.

Mill: A plant where ore is concentrated by one or more beneficiation methods.

Mine: An opening or excavation in the earth for the purpose of excavating minerals.

Mining: The process of obtaining useful minerals from the earth's crust or from mine wastes.

Mine Water: Water that must be removed from the mine to gain or facilitate access to the ore body. For surface mines, mine water can originate from precipitation or groundwater flows into the pit. In underground mines, mine water originates from groundwater aquifers that are intercepted by the mine. (EIS Guidance)

Mineral Rights: The ownership of the minerals under a given surface area, with the right to remove the minerals. (Dictionary)

Net Neutralization Potential (NNP): A method to evaluate the potential of a waste or material to generate more acid products than can be neutralized in the waste/material, and thus to generate acid drainage. NNP is calculated as the difference between acid production potential (AP) and neutralization potential (NP). Another common method is the ratio of NP to AP.

Neutralization Potential (NP): The measure of carbonate material in mined materials or mine workings, which is then theoretically available to neutralize acid generated by the materials/workings.

Ore: A natural mineral compound or mineral aggregate containing precious or other valuable metals (or, less commonly, non-metallic minerals) in sufficient quantities, grade, and chemical combination as to make extraction commercially viable.

Overburden: Material of any nature, consolidated or unconsolidated, that overlies the ore that must be removed to expose the ore body or deposit during mining.

Oxide Ore/Mineral: Metalliferous minerals that have been altered, by weathering and surface water, into oxides, carbonates, or sulfates. Prior to mining, oxidation is a function of natural weathering and any acid generation occurs extremely slow. Mining activities greatly increase the surface area of mine waste and workings that are exposed to weathering agents and thus greatly increase the rate of the chemical reactions that can generate acid drainage. In addition, cyanidation processes for gold recovery, including heap leaching, are most efficient on oxide ores or on sulfide or carbonaceous ores that have been artificially oxidized (e.g., by autoclaving or chlorination or biotreatment).

Pad: The prepared surface and base of a heap that is leached to recover precious metals. The pad can be as simple as compacted native soils, but is more commonly a multiple liner system overlying a compacted undersurface. Often, the terms "pad" or "heap leach pad" are used to refer to the entire heap leach system, including both the liner system and the heap itself.

Placer Deposit: A mass of gravel, sand, or similar material resulting from the crumbling and erosion of solid rocks and containing particles or nuggets of gold, platinum, tin, or other valuable minerals.

Plan of Operations/Operating Plan: A detailed description of the site and the proposed operation, including measures that will be taken to prevent or mitigate environmental degradation and to reclaim the site to regulatory standards. For operations that meet specified size and operational conditions, operators must submit proposed plans and land management agencies (e.g., Bureau of Land Management, US Forest Service) must approve the plans before operations can commence.

Pregnant Solution: Metal-laden leachate solution that is captured at the bottom of a heap or dump that is being leached to dissolve metals from the ore. Metal values (gold, silver, or copper) are then recovered from the pregnant solution, which then becomes barren solution that is typically refortified and reapplied to the heap or dump.

Processing: The further treatment of ores and minerals following extraction and/or beneficiation for the purpose of removing unwanted parameters, improving the quality or purity grade of the desired product, and serving to produce a final mineral product or an intermediate to final mineral product. In common usage, the term "processing" may be used to refer to various beneficiation processes.

Reclamation: Actions to minimize the environmental disruption from mining and mineral processing operations and provide for the rehabilitation of land affected by mining and mineral processing operations through the use of plant cover, soil stabilization, natural system restoration, or other measures appropriate to the subsequent use of the land. In some uses, "reclamation" includes chemical and physical stabilization of the mine site (i.e., "closure").

Refining: The purification of crude metallic products into purer forms. (Dictionary)

Roast: The heating of ores that contain carbonaceous material in order to transform organic carbon into inorganic carbon. Carbonaceous ores may be roasted to increase gold recovery efficiency, since organic carbon greatly reduces gold dissolution by cyanidation.

Shaft: A vertical or steeply inclined opening from the surface down through the strata to the mineral to be developed. (Dictionary)

Sintering: The use of prolonged heat treatment to agglomerate small particles to form larger particles, cakes, or masses without complete fusion or melting. Sintering is used to make fine material into larger or coarser particles more suitable for further beneficiation or processing.

Smelting: The chemical reduction of a metal from its ore (more commonly, from its concentrated ore) by a process that usually involves fusion, so that the impurities in the material separate as lighter and more fusible slags and thus can be readily removed from the reduced metal.

Solvent Extraction: A separation technique that is carried out by causing an organic solvent to come into contact with an aqueous solution containing dissolved mineral values. At the interface of the two liquids, the mineral values are transferred from the aqueous solution to the organic solvent, which is selected to recover only the desired metal. The mineral value is then removed from the solvent using a different aqueous solution. The solvent remains chemically unchanged and is typically regenerated and reused. Solvent extraction is commonly used to remove copper from ore leach solutions.

Static Test: One of two major categories of tests used to predict the occurrence of acid drainage from mine wastes or mine workings (kinetic tests comprise the other category). Static tests are typically based on bulk analyses of samples at one point in time. Typically, results are used to measure and compare various measures of acid potential (AP) and neutralization potential (NP), through many acid-base-accounting (ABA) and other methods. Static tests cannot predict long-term trends in drainage chemistry, although they may be useful in determining whether acid drainage is likely to occur at some later time.

Subore: See ore. Subore is mined material that has lower concentrations of the desired metal than ore. Subore may be managed separately from waste rock in the event that future beneficiation and metals recovery becomes economical.

Sulfide Ore/Mineral: Ore in which sulfide minerals predominate. Sulfides of many metals (e.g., zinc, copper, iron, arsenic) are considered “cyanicides,” which destroy cyanide or interfere with gold-cyanide reactions. As a result, some sulfide ores may require roasting or other artificial oxidation to increase gold recovery efficiency. In addition, exposure of sulfide minerals in mine waste or mine workings to oxygen and water can accelerate oxidation and result in acid generation and the mobilization of heavy metals in acid drainage.

Tailings: The coarsely and finely ground portions of mined material that has been separated from the valuable minerals during beneficiation (crushing, grinding, and concentration). The physical and chemical nature of the tailings varies according to the ore being milled and the milling operations used to beneficiate the ore.

Waste Rock: Non-mineralized and low-grade mineralized rock removed from above or within the ore body during extraction activities. Waste rock includes granular, broken rock, and soils ranging in size from fine sand to large boulders, with the fines content largely dependent on the nature of the formation and the methods employed during mining.

CHAPTER IX

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