COPPER

A.   Commodity Summary

The physical properties of copper, including malleability and workability, corrosion resistance and durability, high electrical and thermal conductivity, and ability to alloy with other metals, have made it an important metal and production input to a number of diverse industries.[1,2] Copper deposits are found in a variety of geologic environments, which depend on the rock-forming processes that occurred at a particular location. These deposits can be grouped in the following broad classes: porphyry and related deposits, sediment-hosted copper deposits, volcanic-hosted massive sulfide deposits, veins and replacement bodies associated with metamorphic rocks, and deposits associated with ultramafic, mafic, ultrabasic, and carbonatite rocks. The most commonly mined type of copper deposit, porphyry copper, is found predominantly in areas along the western continental edges of North and South America, as well as in the southwestern United States, associated with large granite intrusions.[3,4]

Copper occurs in about 250 minerals; however, only a few of these are commercially important.[5] Deposits considered to be economically recoverable at current market prices may contain as little as 0.5 percent of copper or less, depending on the mining method, total reserves, and the geologic setting of the deposit.[6] Most copper ores contain some amount of sulfur-bearing minerals. The weathering environment affecting the ore body following deposition is determined mainly by the availability of oxygen. Ores exposed to air tend to be oxidized, while those in oxygen poor environments remain as sulfides.[7]

The United States is the second largest copper producer in the world. Next to Chile, the United States had the largest reserves (45 million metric tons) and reserve base (90 million metric tons) of contained copper. In 1994, domestic mine production rose to slightly more than 1.8 million metric tons valued at about $4.4 billion. The principal mining states, in descending order, Arizona, Utah, New Mexico, Michigan, and Montana, accounted for 98 percent of domestic production; copper was also recovered at mines in seven other states. Eight primary and five secondary smelters, nine electrolytic and six fire refineries, and 15 solvent extraction-electrowinning plants were operating at years end. Refined copper and direct melt scrap were consumed at about 35 brass mills; 15 wire rod mills; and 750 foundries, chemical plants, and miscellaneous consumers.[8] Exhibit 1 presents the names and locations of the mining, smelting, refining, and electrowinning facilities located in the United States. As available, Exhibit 1 also presents information on potential site factors indicating whether the facility is located in a sensitive environment.

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[1] "Copper," Kirk-Othmer Encyclopedia of Chemical Technology, 4th Ed., Vol. VII, 1993, p. 381.

[2] U.S. Environmental Protection Agency, Technical Resources-Document Extraction and Beneficiation of Ores and Minerals: Volume 4 Copper, Office of Solid Waste, 1993d, p. 3.

[3] "Copper," 1993, Op. Cit., p. 384.

[4] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 7.

[5] Ibid., p. 9.

[6] Ibid., p. 7.

[7] Ibid., p. 9.

[8] Edelstein, Daniel L, from Minerals Commodities Summaries, U.S. Bureau of Mines, January 1995, pp. 50-51.

EXHIBIT 1

SUMMARY OF COPPER MINING, SMELTING, REFINING, AND ELECTROWINNING FACILITIES[a]

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
ASARCO	El Paso, TX	Smelting	
ASARCO	Amarillo, TX	Electrolytic Refining	
ASARCO	Ray, AZ	Electrowinning	
ASARCO	Hayden, AZ	Smelting and Electrowinning	
Burro Chief Copper Mine	Tyrone, NM	Extraction and Electrowinning	
Chino Mines Company	Hurley, NM	Smelting/Fire Refining	100 year floodplain, karst terrain, fault area, private wells within 1 mile
Copper Range	White Pine, MI	Open Pit Mining, Smelting and Refining	fault area
Cyprus Pinos Altos Mine	Silver City, NM	Extraction	
Cyprus	Claypool, AZ	Smelting, Refining, and Electrowinning	
Cyprus Casa Grande Mine	Casa Grande, AZ	In-situ Extraction and Roasting	
Cyprus Miami Mining Corp.	Claypool, AZ	Heap Leaching	fault area, private wells within 1 mile
Cyprus Mineral Park Corp.	Kingman, AZ	Dump Leaching	
Cyprus Sierrita/Twin Buttes	Green Valley, AZ	Heap Leaching	
Cyprus Mining	Bagdad, AZ	Electrowinning	
Cyprus Bagdad Copper Mine	Bagdad, AZ	Heap Leaching and Milling	
Flambeau Copper Mine	Salt Lake City, UT	Extraction	
Gibson Mine	Mesa, AZ	Strip and In-situ Extraction	
Johnson Camp Mine	Tucson, AZ	Heap Leaching	
Kennecott	Garfield, UT	Smelting and Refining	low pH and metals contamination of ground water
Magma Mine	Superior, AZ	Undercutting and Filling (Mining)	
Magma	San Manuel, AZ	Smelting, Refining, and Electrowinning	public and private wells within 1 mile
Mineral Park Mine	Kingman, AZ	Extraction	
Mission Unit	Sahuarita, AZ	Extraction	
Montanore Mine	Libby, MT	Extraction	
Morenci Mine	Morenci, AZ	Heap Leaching	
Noranda	Casa Grande, AZ	Electrowinning	

[a] - ICF Incorporated, Mining and Mineral Processing Facilities Database, August 1992.

EXHIBIT 1 (Continued)

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
Oracle Ridge Mine	San Manuel, AZ	Extraction	
Phelps Dodge	Morenci, AZ	Electrowinning	
Phelps Dodge	Playas, NM	Smelting	fault area
Phelps Dodge	El Paso, TX	Refining	fault area, public and private wells within 1 mile
Phelps Dodge	Hurley, NM	Smelting and Electrowinning	
Pinos Altos Mine	Silver City, NM	Extraction	
Pinto Valley Operations	Miami, AZ	Extraction and Electrowinning	
Pinto Valley	Pinto Valley, AZ	Electrowinning	
Ray Complex	Hayden, AZ	Extraction	
San Manuel Div. Mine	San Manuel, AZ	Extraction	
San Pedro Mine	Truth or Consequence, NM	Extraction	
Silver Butte Mine	Riddle, OR	Extraction	
Silver Bell Unit	Marana, AZ	Extraction	
St. Cloud Mining Co.	Truth or Consequence, NM	Extraction	
Sunshine Mine	Kellog, ID	Extraction	
Tennessee Chemical	Copperhill, TN	Closed	
Tyrone Branch Mine	Tyrone, NM	Dump Leaching and Electrowinning	
Western World Copper Mine	Marysville, CA	Extraction	
Yerington Mine	Tucson, AZ	Extraction	

[a] - ICF Incorporated, Mining and Mineral Processing Facilities Database, August 1992.

EXHIBIT 1 (Continued)

The majority of the copper produced in the United States is used in the electrical industry; it is used for a wide range of wiring applications (from power transmission lines to printed circuit boards), in microwave and electrical tubes, motors and generators, and many other specialized applications where its high electrical and thermal conductivity can be employed. While copper has been replaced in some applications by aluminum (e.g., for overhead power lines) and fiber optics (e.g., in telecommunications), its durability, strength, and resistance to fatigue assure its continued use in the electrical industry. These latter three characteristics also make copper and copper alloys a valued material in construction and containment (e.g., pipes and tanks), and in other activities where endurance and resistance to corrosion are required.[9]

Primary production of copper in the United States has steadily increased in the early 1990s. Total apparent consumption has risen from 2,170,000 metric tons in 1990 to 2,800,000 metric tons in 1994. Approximately 42 percent of the 1994 domestic consumption of copper went to building and construction industries, while 24 percent was used by the electrical and electronic products industries. Industrial machinery and equipment consumed 13 percent, transportation equipment consumed 12 percent and consumer and general products consumed the remaining 9 percent.[10] Clearly, the development of new infrastructure in the United States and abroad would increase the worldwide demand for copper, but consumption per unit of new gross product would be less than that in the past because substitutes for copper are often used in a number of industries. For example, new telephone infrastructure is being based upon fiber optics technology rather than copper to a significant degree. Continued re-opening of mothballed facilities, expansion of existing facilities, and development of new mines could lead to copper supplies increasing faster than demand.[11,12]

B.   General Process Description

1.   Discussion of the Typical Production Process

The two major processes employed in the United States to recover copper from ores are classified as either (1) pyrometallurgical methods, or (2) hydrometallurgical methods. Pyrometallurgical methods consist of conventional smelting technology, and are widely used. Hydrometallurgical methods involve leaching and recovery by precipitation or electrowinning, and are gaining in popularity, although they do not entirely eliminate the problems found in pyrometallurgical processing. For example, in 1984 100,180 tons of copper was produced by solvent extraction and electrowinning (SX/EW), while in 1992 439,043 tons were produced by SX/EW.[13] Many within the industry believe that hydrometallurgical operations are only economically attractive for producing 30,000 metric tons of copper product per year or less.[14,15]

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[9] Ibid.

[10] Ibid.

[11] Ibid.

[12] U.S. Environmental Protection Agency, "Primary Copper Processing," Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, p. 6-2.

[13] "Copper," 1993, Op. Cit., p. 412.

[14] Ibid., p. 408.

[15] Keith R. Suttill, "Pyromet or Hydromet?" Engineering and Mining Journal, 191, May 1990, p. 31.

EXHIBIT 1 (Continued)

2.   **Generalized Flow Diagram**

Exhibit 2 presents a flow diagram of the typical operations involved the production of copper from ore.

Extraction and Beneficiation Operations

Prior to either pyrometallurgical or SX/EW hydrometallurgical operations, the ore (which often contains less than one percent copper) is crushed and ground with water and placed in a concentrator. The rock/water slurry is subjected to physical and chemical actions (i.e., air sparging and hydrophobic chemical reagents) inside a flotation tank. The chemical reagents assist the flotation process by acting as frothing and collector agents. Methylisobutyl carbonal (MIBC) is a typical frothing agent, and sodium xanthate, fuel oil, and VS M8 (a proprietary formulation) are typical collector agents. As a result of the physical and chemical actions, the copper value rises to the surface of the flotation unit as a froth.[16]

The material remaining on the bottom of the flotation tank (waste rock or "gangue"), is partially dewatered and then discharged to tailing ponds for subsequent disposal.[17] In cases where the copper ore contains a large amount of clay minerals, "slime" (a mixture of clay minerals and copper values) often forms and is separated from the gangue for further copper recovery. The slime is reground and subjected to flotation to remove the copper value. Once the copper value is removed, the slime is ultimately managed/disposed with the gangue.[18,19]

The concentrate resulting from the flotation circuit contains approximately 30 percent copper and, in some instances, may also contain significant recoverable concentrations of molybdenum. If molybdenum is readily recoverable, as it is at Magma Copper (Arizona), the concentrate is sent to the molybdenum plant for recovery; otherwise, the concentrate is ready for subsequent pyrometallurgical or SX/EW hydrometallurgical operations.[20,21] Alternatively, the concentrate can be dewatered and the dry product may either be stored for further processing or shipped to another facility for processing. The collected water is usually recycled in the milling circuit.

At a molybdenum recovery plant, such as the one at Magma Copper (Arizona), the copper concentrate contains approximately one percent molybdenum disulfide (which in itself is a saleable co-product). To isolate the molybdenum from the copper concentrate, the concentrate undergoes additional flotation steps. The copper concentrate is added to a rougher flotation cell where sodium cyanide is added to suppress the copper, thus causing the molybdenum to float to the surface. The copper concentrate falls to the bottom and the underflow is sent for drying and thickening prior to smelting. The molybdenum-containing overflow is sent to additional cleaner and recleaner circuits. At the last recleaner circuit, 70 percent of the overflow is filtered and dried, and the remaining 30 percent is returned to the filter at the

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[16] U.S. Environmental Protection Agency, <u>Trip Report -- Site Visit to Magma Copper and Cyprus Miami Copper Mines," Draft Memorandum</u>, Office of Solid Waste, April 1994b, p. 6.

[17] <u>Ibid</u>., p. 6.

[18] "Copper," 1993, <u>Op. Cit.</u>, pp. 388-92.

[19] U.S. Environmental Protection Agency, 1993d, <u>Op. Cit.</u>, p. 53.

[20] "Copper," 1993, <u>Op. Cit.</u>, pp. 388-92.

[21] U.S. Environmental Protection Agency, 1993d, <u>Op. Cit.</u>, p. 53.

EXHIBIT 1 (Continued)

EXHIBIT 2

Process Flow Diagram for the Production of Copper

Graphic Not Available.

EXHIBIT 1 (Continued)

beginning of the recleaner circuit. The filtered, dry molybdenum disulfide product (95 percent) is packed into 55-gallon drums and sold as molybdenite.[22]

Pyrometallurgical Processing

Pyrometallurgical processes employ high-temperature chemical reactions to extract copper from its ores and concentrates. These processes generally are used with copper sulfides and in some cases high-grade oxides.[23] Depending on the copper mineral and the type of equipment, pyrometallurgical recovery may take as many as five steps: roasting, smelting, converting, fire refining, and electrorefining. The products from smelting, converting, fire refining in an anode furnace, and electrolytic refining are copper matte, blister copper, copper anodes, and refined copper, respectively.[24] Roasting dries, heats, and partially removes the sulfur and volatile contaminants from the concentrated ore to produce a calcine suitable for smelting.[25] Modern copper smelters generally have abandoned roasting as a separate step, and have combined this function with the smelting furnace. However, in older systems using multiple brick hearths, the copper concentrate moves from the top of the hearth towards the base, while air is injected counter-current to the concentrate. The roasted ore leaves through the bottom brick hearth and sulfur dioxide (2-6 percent) exits through the top.[26]

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. The smelter furnace produces two separate molten streams: copper-iron-sulfide matte, and slag, as well as sulfur dioxide gas.[27] The smelter slag, essentially a mixture of flux material, iron, and other impurities, is a RCRA special waste. The slags from some smelting furnaces are higher in copper content than the original ores taken from the mines, and may therefore be sent to a concentrator for copper recovery.[28,29] Tailings from flotation of copper slag are a second RCRA special waste. Reverberatory furnaces are being replaced by electric or flash furnaces because reverberatory furnaces are not as energy efficient, and they produce large volumes of low concentration SO_2 gas, which is difficult to use in sulfur recovery.[30] The gases produced by electric smelting are smaller in volume, lower in dust (less than 1 percent), and have a higher SO_2 concentration, which allows better sulfur recovery in an acid plant.[31] Gases from smelting operations contain dust and sulfur dioxide. The gases are cleaned using electrostatic precipitators and then are sent to the acid plant, which converts the sulfur dioxide-rich gases to sulfuric acid (a useable and/or saleable product).[32]

Magma has constructed a new flue dust leaching (FDL) facility to recover copper from several smelter by-product streams. Feedstocks to the FDL facility include flash furnace dust (20-25 percent copper, 1.3 percent arsenic),

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[22] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 7.

[23] Office of Technology Assessment, Copper: Technology and Competitiveness, OTA-E-67, Washington, DC: U.S. Government Printing Office, September 1988, p. 133.

[24] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-2.

[25] Office of Technology Assessment, 1988, Op. Cit., p. 134.

[26] "Copper," 1993, Op. Cit., p. 394-95.

[27] Process upsets sometimes require the copper concentrate to be diverted from the smelter. EPA is investigating the current management techniques, and their environmental implications.

[28] "Copper," 1993, Op. Cit., p. 393.

[29] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-3.

[30] K. Yoshiki-Gravelsins, J. M. Toguri, and R. T. Choo, "Metals Production, Energy, and the Environment, Part II: Environmental Impact," Journal of Mines, 45, No. 8, August 1993, p. 23.

[31] Ibid., p. 27.

[32] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 8.

EXHIBIT 1 (Continued)

converter flue dust (80 percent copper, 0.01 percent arsenic), acidic bleed solution from the Lurgi scrubbers (3.6 g/L copper, 0.4 g/L arsenic, 3.5 g/L acid pH 1.6). (Lurgi scrubbers are pollution control devices for smelter converter offgas.) These feedstocks are stored in bins or slurry tanks prior to entering a series of agitator leach vessels. Sulfuric acid (93 percent concentration) is added to dissolve the copper into solution. The remaining solids are thickened, washed, and filtered. The resulting filter cake is sent back to the flash furnace for smelting. The copper sulfate-rich leachate is purified in a dedicated solvent extraction unit, where an extremely concentrated copper sulfate solution (one that can easily be crystallized into commercial grade copper sulfate crystals) is generated. The crystals are either sold "as is" or are sent to the main solvent extraction circuit. [33]

In the converter (the most common being the Peirce-Smith converter, followed by the Hoboken converter and the Mitsubishi continuous converter), a high silica flux and compressed air or oxygen are introduced into the molten copper matte. Most of the remaining iron combines with the silica to form converter slag, a RCRA special waste. After removing the slag, additional air or oxygen is blown in to oxidize the sulfur and convert the copper sulfide to blister copper that contains about 99 percent copper; the sulfur is removed in the form of SO_2 gas, which reports to an acid plant where it is converted to high grade sulfuric acid. Depending on the efficiency of the acid plant, differing amounts of SO_2 are emitted to the atmosphere. Some facilities have combined the smelting furnace and converter into one operation, such as the one used by Kennecott (i.e., the Kennecott-Outokumpo flash converting process). [34,35] In the interest of conserving energy and improving efficiency, many companies are now employing flash smelting (such as the Outokumpo, Inco, Mitsubishi, or Noranda processes) to produce matte feed. [36]

Oxygen and other impurities in blister copper must be removed before the copper can be fabricated or cast into anodes for electrolytic refining. Blister copper is fire refined in reverberatory or rotary furnaces known as anode furnaces. When co-located with a smelter or converter, the furnace may receive the blister copper in molten form so remelting is unnecessary. Air is blown in to oxidize some impurities; flux may be added to remove others. The residual sulfur is removed as sulfur dioxide. A slag is generated during anode furnace operation. This slag is also a component of the RCRA special waste. The final step in fire refining is the reduction of the copper and oxygen removal by feeding a reducing gas such as ammonia, reformed gas, or natural gas into the copper while it is still in the anode furnace. The molten copper then is cast into either anodes for further electrolytic refining or wire-rod forms. [37,38]

Electrolytic refining (or electrorefining) purifies the copper anodes, by virtually eliminating the oxygen, sulfur, and base metals that limit copper's useful properties. In electrorefining, the copper anodes produced from fire-refining are taken to a "tank house" where they are dissolved electrolytically in acidic copper sulfate solution (the electrolyte). The copper is electrolytically deposited on "starter" sheets of purified copper to ultimately produce copper cathodes (relatively pure copper with only trace contaminants -- less than a few parts per million) for sale and/or direct use. The concentration of copper and impurities in the electrolyte are monitored and controlled. As necessary, the electrolyte is purified (e.g., copper is removed from the electrolyte in electrowinning cells), and the resulting impurities (left on the bottom of the electrolytic cells and electrowinning cells -- often referred to as "anode slimes" and "muds or slimes", respectively) are processed for recovery of precious metals (gold, silver, platinum, palladium), bismuth, selenium, and tellurium. [39,40] Electrorefining also produces various aqueous waste streams (e.g., process wastewater, bleed electrolyte)

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[33] Ibid., p. 9.

[34] "Copper," 1993, Op. Cit., p. 396.

[35] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 6-3 - 6-4.

[36] "Copper," 1993, Op. Cit., p. 396.

[37] Ibid., p. 399-400.

[38] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-4.

[39] Note to the reader: we are currently trying to resolve conflicting information obtained from EPA's recent site-visits and that found in various literature to determine whether slimes are generated in electrowinning cells.

[40] "Copper," 1993, Op. Cit., pp. 401-404.

EXHIBIT 1 (Continued)

that must be treated and discharged, reused, or disposed of in some manner. Many of the facilities use a wastewater treatment operation to treat these wastes. The solid residual from these treatment operations is a calcium sulfate sludge, which is yet another RCRA special waste generated by the primary copper sector.[41]

Hydrometallurgical Beneficiation

Hydrometallurgical copper recovery is the extraction and recovery of copper from ores using aqueous solutions. Hydrometallurgical operations include the following: (1) acid extraction of copper from oxide ores; (2) oxidation and dissolution of sulfides in waste rock from mining, concentrator tailings, or *in situ* ore bodies (e.g., low grade oxide and sulfide mine wastes); and (3) dissolution of copper from concentrates to avoid conventional smelting.[42] In summary, the copper-bearing ore (and in some cases, the overburden) is leached, then the copper is recovered from the pregnant leachate through precipitation, or solvent extraction and electrowinning (SX/EW).[43]

The simplest form of hydrometallurgical beneficiation of low grade ores, waste rock, and overburden practiced at large, open-pit copper mines is dump leaching. In dump leaching, the raw material is leached using a dilute sulfuric acid solution. There are several other types of leaching operations (progressing from least capital intensive and inefficient -- using the rock "as is" -- to most capital intensive and efficient -- using ground ore): *in situ*, heap or pile, vat, and heat or agitated leaching. In some cases, roasting is employed prior to leaching in order to enhance the leachability of the material. In roasting, heat is applied to the ore, which enhances its amenability to leaching without destroying the physical structure of the ore particles. The roasted material is then subjected to leaching (as described above). The copper-rich leachate (referred to as "pregnant solution") is subjected to further beneficiation while the waste material is either left in place (in the case of dump, *in situ*, heap, or pile leaching) or managed in tailing ponds (in the case of vat, heat, or agitated leaching). The major potential environmental impact of hydrometallurgical beneficiation involves acid seepage into the ground. In addition, hydrometallurgical sludges may contain undissolved metals, acids, and large quantities of water.[44]

Copper is removed from the pregnant leachate through either iron precipitation (or cementation) or solvent extraction and electrowinning. In cementation, which was once the most popular method for recovering copper from the pregnant leachate, the leachate is combined with detinned iron in a scrap iron cone (such as the Kennecott-Precipitation Cone) or vibrating cementation mill, where the detinned iron replaces the copper in the solution. The copper precipitates are removed for subsequent hydrometallurgical refining (electrowinning) or pyrometallurgical processing.[45,46]

In solvent extraction (now, the most popular process), an organic chemical (chelator) that binds copper but not impurity metals is dissolved in an organic solvent (often kerosene) and is mixed with the pregnant leach solution. The copper-laden organic solution is separated from the leachate in a settling tank. Sulfuric acid is then added to the pregnant organic mixture, which strips the copper into an electrolytic solution ready for electrowinning. The barren leachate (or raffinate) is sent back to the leaching system. Electrowinning is the recovery of copper from the loaded electrolyte solution produced by solvent extraction, yielding refined copper metal. When the iron concentration becomes too high in the electrowinning cells, some solution is bled off and sent to the SX unit for further copper recovery. The copper-poor (or lean) electrolyte from electrowinning is returned to the SX plant. Excess lean electrolyte from the SX unit is returned to the raffinate pond. This operation is functionally equivalent to electrolytic refining.[47,48]

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[41] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-4.

[42] "Copper," 1993, Op. Cit., p. 408.

[43] Office of Technology Assessment, 1988, Op. Cit., p. 140.

[44] K. Yoshiki-Gravelsins, J. M. Toguri, and R. T. Choo, 1993, Op. Cit., p. 27.

[45] "Copper," 1993, Op. Cit., p. 410.

[46] Office of Technology Assessment, 1988, Op. Cit., pp. 140-142.

[47] "Copper," 1993, Op. Cit., pp. 412-13.

[48] Office of Technology Assessment, 1988, Op. Cit., p. 142.

EXHIBIT 1 (Continued)

We note that at Magma Copper (Arizona), the pregnant leach solution (PLS) is collected in the PLS feed pond, where other inputs to the PLS feed pond include liquids from *in-situ* leaching, Gould Solution, and TNT filter cake. Gould Solution is produced from the electrolytic refining of copper foil at one facility in Chandler, AZ. The spent electrolyte solution (containing 100 g/L sulfuric acid and 60 g/L copper) is trucked to Magma Copper, where it is added directly to the PLS feed pond. Magma Copper has proposed to accept filter cakes consisting of copper oxide mud from copper chloride etching solution generated during the production of circuit boards. This material (TNT filter cake) would be mixed with the PLS feed to the SX unit.[49]

3. Identification/Discussion of Novel (or otherwise distinct) Process(es)

Additional pyrometallurgical technologies still under development include the solid matte oxygen converting (SMOC) process and continuous total pressure oxidation process. The SMOC process developed by Kennecott, is a one-step smelting process designed to eliminate the hot matte and slag transfers between smelting and converting, thereby reducing their attendant fugitive emissions. In the total pressure oxidation process, chalcopyrite ($CuFeS_2$) can be hydrothermally oxidized directly to digenite (CuS) inside a single, continuous autoclave reactor. The enriched solid residue (super concentrate) is separated from the liquor, containing ferrous sulfate and sulfuric acid, and the upgraded concentrate can proceed directly to smelting. The acid solution can be used in heap or dump leaching.[50] Total pressure oxidization is especially well-suited for concentrates with a high copper to sulphur ratio.[51]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in Section B.

EPA determined that for this specific mineral commodity sector, depending on the specific process, the beneficiation/processing line occurs between flotation and furnacing or between iron precipitation and furnacing because furnacing (or smelting) significantly alters the physical/chemical structure of the beneficiated ore. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing

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[49] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 16.

[50] Robert W. Bartlet, "Copper Super-Concentrates--Processing, Economics, and Smelting," EPD Congress, 1992, pp. 652-653.

[51] J. A. King, D. A. Knight, and D. B. Dreisinger, "The Total Pressure Oxidation of Copper Concentrates," The Minerals, Metals and Materials Society, 1993, p. 735.

EXHIBIT 1 (Continued)

waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C.   Process Waste Streams

As discussed above (and shown in Exhibit 2), the extraction, beneficiation, and processing of copper leads to the generation of numerous solid, liquid and gaseous wastes, which depending on the material, may be recycled or purified prior to disposal. The generation, treatment, and management of each of these wastes is discussed below.

1.   Extraction/Beneficiation Wastes

Wastes generated from the extraction and beneficiation of copper from copper-bearing ores are exempt from RCRA Subtitle C and the scope of BDAT determinations. Wastes from the extraction/beneficiation of copper-bearing ores are discussed below.

Waste rock. This waste from mining operations, along with overburden, is generated from the actual removal of copper ore from the ground and contains little or no recoverable copper values. These materials are typically hauled from the mine site and are disposed of in on-site waste rock dumps. At Magma Copper (Arizona), waste rock is left in place; at other facilities, however, the waste rock may be hauled to the surface and disposed.[52] In 1980, more than 282 million tons of waste rock were disposed.[53]

Tailings (or gangue). This waste results from the flotation of ground ore/water slurry. The composition of tailings varies according to the characteristics of the ore; this waste is comprised of very fine host rock and nonmetallic minerals. Tailings are sent to tailings impoundments for disposal, but may first be dewatered in thickeners. For example, at Magma Copper (Arizona) tailings from the copper and molybdenum flotation processes are sent to a hydroseparator for dewatering. The hydroseparator underflow is sent to a repulper and the slurry is discharged to the tailings ponds for disposal. The hydroseparator overflow is sent to a thickener, where the solids (underflow) are sent to the repulper and the liquid stream (water overflow) is reused in the flotation circuit. Tailings generated during the flotation processes are excluded from RCRA Subtitle C regulation under the Bevill Amendment.[54] In 1985, the industry disposed of more than 189 million tons of gangue.[55]

Slime. A clay/copper material called slime is often generated during the flotation of copper ore containing a large amount of clay minerals. Slime is separated from the gangue and is reground and refloated to remove additional copper value. The slime is ultimately disposed of along with the tailings. There is no information on the quantity of slime generated annually.[56] We note that this "slime" is much different in composition than the "slimes or muds" generated by electrolytic refining (see below).

Solvent Extraction/Electrowinning. These operations result in the generation of several liquid and semi-liquid wastes. Often these materials are still either useful or rich in values and can be reused or recycled. The following waste streams are non-uniquely associated and, therefore, not subject to the Bevill Exclusion:

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[52] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 10.

[53] U.S. Environmental Protection Agency, 1993d, Op. Cit., pp. 50-51.

[54] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 10.

[55] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 53-54.

[56] "Copper," 1993, Op. Cit., p. 388-92.

EXHIBIT 1 (Continued)

Slimes or "mud s". These materials result from the dep osition of sediment in electrowinning cells. The se materials often contain valuable quantities of precious metals and are either processed on-site or are drummed and sent off-site fo r recovery.[57] Appro ximately 3,00 0 metric ton s of slimes are ge nerated an nually.[58] (See footnote no . 39.)

Crud (often referred to as "gunk," "grungies," or "grumos"). This waste is generated during solvent extraction. Crud is solid particles associated with oil/water dispersions of varied complexity and typically form stable multi-phase emulsions. Crud is periodically removed from the system. The crud is centrifuged or otherwise treated to remove the organics, which are returned to the solvent extraction circuit for reuse. Site-specific management information is available for several companies. At the Chino Mines Company (Santa Rita, NM), the recovered organic is filtered using Filtrol No.1 montmorillonite clay and then is returned to the SX circuit. The resulting solids and aqueo us material are disposed o f in the tailing ponds.[59] In some cases, however, the resulting solids contain sufficient quantities of precious metals to warrant recovery (off-site).[60] We note that at both the Magma Copper Company's San Manuel, AZ facility and the Cyprus Mines' Miami, AZ facility, crud is recycled into the raffinate pond which is linked to, and forms, an integral part of the SX/EW processing circuit.[61,62] Appro ximately 2,00 0 metric ton s of crud is generated ann ually.[63]

Raffinate or barren leachate. This waste is generated when the pregnant leachate is stripped and is recycled back to the leaching circuit. Approx imately 70,0 36,000 metric tons o f raffinate is genera ted annually.[64,65] At Cerro Copper Products Company (a secondary copper facility) in Sauget, IL, an electrolyte purification - nickel recovery syste m was installed and bega n operating in late 1990, thereby allow ing the recov ery of nickel sulfate and cessation of the discharge of raffinate.[66]

Spent Kerosene. Commonly used as the organic material in solvent extraction, spent kerosene is purified using filter clay. The resulting impurities or "grungies" are either sent to the heap-leaching area or are disposed of with tailings.[67]

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[57] "Copper," 1993, Op. Cit., pp. 401-404.

[58] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume I, Office of Solid Waste, August 1992, p. I-3.

[59] Tom Burniston, James N. Greenshield, and Peter E. Tetlow, "Crud Control in Copper SX Plants," Engineering and Mining Journal, 193, No. 1, January 1992, pp. 32-33.

[60] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 54.

[61] RTI Survey 100750, National Survey of Solid Wastes from Mineral Processing Facilities, Magma Copper Co., San Manuel, AZ, 1989.

[62] Tom Burniston, James N. Greenshield, and Peter E. Tetlow, 1992, Op. Cit., p. 34.

[63] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[64] The 1992 NIMPW Characterization Data Set indicates that 70,036,000 metric tons of raffinate are generated annually. We are currently trying to verify this number and will revise it in the near future (if appropriate).

[65] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[66] John L. Sundstrom, "Recycle of Tankhouse Solutions at Cerro Copper Products Electrolytic Copper Refinery in Sauget, Illinois," Residues and Effluents - Processing and Environmental Considerations, The Minerals, Metals and Materials Society, 1991, pp. 527-537.

[67] U.S. Environmental Protection Agency, 1993d, Op. Cit., pp. 114-115.

EXHIBIT 1 (Continued)

2.   Mineral Processing Wastes

Smelting and Refining operations generate numerous solid, liquid, and gaseous wastes, several of which are Bevill Exempt wastes including **furnace slags**, **anode casting slags**, and **wastewater treatment sludges**. Other wastes are described below:

Spent Bleed electrolyte. Spent electrolyte results from electrolytic cells. Normally, spent electrolyte is purified in liberator cells. Liberator cells are similar to normal electrolytic cells, but they have lead anodes instead of copper anodes. The electrolyte is cascaded through the liberator cells, and an electric current is applied. Copper in the solution is deposited on copper starting sheets. As the copper in the solution is depleted, the quality of the copper deposit is degraded. Liberator cathodes containing impurities are returned to the smelter to be melted and cast into anodes. Purified electrolyte is recycled to the electrolytic cells. Any bleed electrolyte can be neutralized with mill tailings and disposed of in tailing ponds or pumped to a raffinate pond, from which it is pumped to on-site copper leaching dumps. Sludge that falls on the floor of the liberator cell is returned to the smelter or sold.[68,69]

Site-specific management information is available for several companies. Cyprus Miami Mining Corp. in Claypool, AZ recycles the bleed electrolyte to the solvent extraction plant.[70] Magma Copper Company's San Manuel facility recycled the bleed electrolyte to the solvent extraction/electrowinning plant for copper recovery.[71] Kennecott Utah Copper's Bingham Canyon, UT facility treats the bleed electrolyte in their wastewater treatment plant.[72] Phelps Dodge Refining Corp. in El Paso, TX sends bleed electrolyte to an electrowinning plant, which produces commercial sulfuric acid, commercial grade nickel sulfate crystals, and water vapor.[73] Approximately 307,000 metric tons of bleed electrolyte are generated annually. Bleed electrolyte exhibits the hazardous characteristics of toxicity (for arsenic, cadmium, chromium, lead, selenium, and silver) and corrosivity.[74] This waste stream is partially recycled and classified as spent material. Additional data are included in Attachment 1.

Tankhouse slimes. Often referred to as "anode slimes", tankhouse slimes are the result of material deposition in electrolytic cells. Slimes contain the constituents in a copper anode that remain insoluble during the electrorefining process and ultimately settle to the bottom of the cells.[75] Generally, slimes generated from copper refining of various ores have the same values and impurities, including gold, silver, platinum group metals, copper, selenium, arsenic, tin, lead, and tellurium. However, their metals concentrations may vary widely, depending on the ore from which the copper

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[68] U.S. Environmental Protection Agency, <u>Revised Draft Wastes from Primary Copper Processing Characterization Report for Cyprus Miami Mining Corporation, Claypool, AZ</u>, Office of Solid Waste, May 1991, p. 5.

[69] U.S. Environmental Protection Agency, <u>Draft Overview of Solid Waste Generation, Management, and Chemical Characteristics in the Primary Copper Smelting and Refining Industry</u>, Industrial Environmental Research Laboratory, Office of Research and Development, October 1984, p. 3-12.

[70] RTI Survey 100156, <u>National Survey of Solid Wastes from Mineral Processing Facilities</u>, Cyprus Miami Mining Corp., Clay Pool, AZ, 1989.

[71] RTI Survey 100750, 1989, <u>Op. Cit.</u>

[72] RTI Survey 100834, <u>National Survey of Solid Wastes from Mineral Processing Facilities</u>, Kennecott Utah Copper, Bingham Canyon, UT, 1989.

[73] RTI Survey 101741, <u>National Survey of Solid Wastes from Mineral Processing Facilities</u>, Phelps Dodge Refining Co., El Paso, TX, 1989.

[74] U.S. Environmental Protection Agency, 1992, <u>Op. Cit.</u>, p. I-3.

[75] James E. Hoffmann, "Advances in the Extractive Metal Metallurgy of Selected Rate and Precious Metals," <u>Journal of Mines</u>, 43, No. 4, 1991, pp. 22-23.

EXHIBIT 1 (Continued)

anodes have been obtained. The raw slimes always have high copper contents, and the selenium content is also usually high. Therefore, normal slime treatment includes initial decopperization of the slimes, followed usually by deselenization. Traditionally, these slimes are then sent to smelting in a doré furnace, followed by refining.[76] A new method of metals recovery gaining popularity is wet chlorination, which uses chlorination and solvent extraction to recover these values.[77] These materials often contain valuable quantities of precious metals and are either processed on-site or are drummed and sent off-site for recovery. Approximately 4,000 metric tons of tankhouse slimes are generated annually.[78] Although no published information regarding waste characteristics was found, we used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for selenium, silver, arsenic and lead. This waste stream is partially recycled and classified as a by-product.

Acid plant blowdown. This waste originates in the gas cleaning section of the acid plant. It is generated from the water spraying of smelter converter gases and consists largely of smelter feed carryover solids. Blowdown has been reported to contain 14 percent sulfate, 15 percent total dissolved solids, 1 percent copper, 1 percent iron and 70 percent water.[79] Acid plant blowdown also may contain significant concentrations (i.e., >1,000 mg/L) of arsenic, cadmium, lead, molybdenum, and selenium (additional data are included in Attachment 1).[80] Approximately 4,847,000 metric tons of acid plant blowdown are generated annually. This waste exhibits the characteristics of toxicity (for arsenic, cadmium, chromium, lead, mercury, selenium, and silver) and corrosivity.[81] This waste is partially recycled and classified as a by-product.

Site-specific management information is available for several facilities. Cyprus Miami Mining Corp. in Claypool, AZ recycles the solid fraction to the smelter and the liquid portion to the solvent extraction plant.[82] The Hidalgo smelter in Playas, NM was scheduled to make process modifications by January 1993. Previously, acid plant blowdown was sent to an evaporation unit. Radial flow scrubbers and additional technology to be determined were scheduled to be installed in the acid plants, thereby eliminating the wastewater.[83] Chino Mining Company in Hurley, NM neutralizes the blowdown with magnesium hydroxide in a settler. The solids are recycled to the smelter and the fluids are recycled to the concentrator.[84] At the Magma Copper Company's San Manuel, AZ facility, the blowdown is neutralized with lime and alkaline tailings, and the resulting mixture is sent to tailings dams.[85] Kennecott Utah Copper in Bingham Canyon, UT sends the blowdown to the wastewater treatment plant and then to the tailings pond.[86]

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[76] M. Devia and A. Luraschi, "A Study of the Smelting and Refining of Anode Slimes to Doré Metal," Copper 91 (Cobre 91), Ottawa, Ontario, Canada, 18-21 Aug. 1991, Pergamon Press, Inc., New York, 1992 p. 210.

[77] James E. Hoffmann, 1991, Op. Cit., p. 23.

[78] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[79] U.S. Environmental Protection Agency, 1991, Op. Cit., pp. 5-7.

[80] U.S. Environmental Protection Agency, Study of Remanded Mineral Processing Wastes Draft Report, Office of Solid Waste, April 1994c, p. 19.

[81] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[82] RTI Survey 100156, 1989, Op. Cit.

[83] RTI Survey 100487, National Survey of Solid Wastes from Mineral Processing Facilities, Hidalgo Smelter, Playas, NM, 1989.

[84] RTI Survey 100495, National Survey of Solid Wastes from Mineral Processing Facilities, Chino Mining Co. Hurley, NM, 1989.

[85] RTI Survey 100750, 1989, Op. Cit.

[86] RTI Survey 100834, 1989, Op. Cit.

EXHIBIT 1 (Continued)

Acid plant thickener sludge. This sludge results from the treatment of weak acid plant blowdown (see above). In the past, this waste stream generally was discharged to either a tailings pond or evaporation pond. Recent site-specific information, however, indicates that this waste stream is no longer generated. Specifically, two facilities filter solids from the blowdown and blend the recovered solids with incoming copper ore for beneficiation/processing. The filtered blowdown is routed to an on-site electrowinning circuit for recovery of copper (and other metals). At a third facility, the blowdown is neutralized with ammonia, then filtered, and the resulting solids are blended with incoming ore. The majority of the filtrate is returned to the sulfuric acid plant for reuse as scrubber water, and the remaining portion of the filtrate is evaporated to recover ammonium sulfate product. At a fourth facility, the blowdown is neutralized with magnesium hydroxide, then filtered, and the resulting solids are blended with incoming ore. The filtrate is reused as make-up water in the flotation circuit. At a fifth facility, the blowdown is first neutralized with alkaline tailings and then discharged to a tailings pond (analysis of the neutralized blowdown indicates that it is not TC characteristic). At a sixth facility, the blowdown is neutralized with lime and then sent to a double-lined, Subtitle C evaporation pond. At a seventh facility, the blowdown is neutralized with lime, combined with other plant wastewaters, and then sent to an unlined evaporation pond (analysis of the combined wastewater indicates that it exhibits the TC characteristic for arsenic, lead, and selenium).[87] Additional data are included in Attachment 1.

Waste Contact cooling water. This waste results from heat exchanging operations, such as those taking place at the smelter. The water used for anode cooling is reported to contain dissolved arsenic, copper, and zinc, and also to pick up aluminum and chlorides, probably from mold dressing compounds.[88] Site-specific management information is available for several companies. The Magma Copper Company's San Manuel, AZ facility recycles the copper anode cooling water to the concentrator.[89] The Kennecott Utah Copper's facility in Bingham Canyon, recycles all but a small fraction to the ore concentrator. The remaining small fraction is discharged under NPDES after treatment.[90] At Cyprus Miami Mining Corp., Claypool, AZ, contact cooling water is returned to the Industrial Water System.[91] Approximately 13,000 metric tons of contact cooling water is generated annually.[92] Although no published information regarding waste characteristics was found, we used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for arsenic. This waste stream is recycled and classified as spent material.

WWTP liquid effluent. Treated effluent from the wastewater treatment plant is either disposed of in the tailings surface impoundments or discharged through a NPDES permitted outflow, therefore it is not included in the analysis. Approximately 4,590,000 metric tons of WWTP liquid effluent is generated annually.[93] We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for lead. Additional data are included in Attachment 1.

Process wastewaters. Various wastewaters result from conveyance, flotation, mixing, dissolution, and cooling operations. Water is used for many things including, seal water in crushers and pumps, for dust suppression and gas scrubbing, in low grade heat extraction from furnace cooling elements and acid plant coolers, sulfuric acid production, anode cooling, steam production, electricity production, potable drinking water, and conveyance of sanitary sewage.[94] Process wastewaters may either be treated on site at wastewater treatment facilities or discharged to tailings ponds,

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[87] U.S. Environmental Protection Agency, 1994c, Op. Cit., pp. 3-4.

[88] U.S. Department of Commerce, Industrial Process Profiles for Environmental Use: Chapter 29 Primary Copper Industry, Industrial Environmental Research Lab, July 1980. p. 89.

[89] RTI Survey 100750, 1989, Op. Cit.

[90] RTI Survey 100834, 1989, Op. Cit.

[91] U.S. Environmental Protection Agency, 1991, Op. Cit., p. 3.

[92] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[93] Ibid.

[94] Christine P. Viecelli, "Comprehensive Water Management Program For a Primary Copper Smelter," Residues and Effluents - Processing and Environmental Considerations," The Minerals, Metals and Materials Society, 1991, p. 82.

EXHIBIT 1 (Continued)

surface impoundments, or to receiving streams. At Claypool, process wastewater is limited to anode casting cooling water. It is mixed with cooling tower effluent and stored for later recycling back to the process.[95] At Magma Copper Company's San Manuel site, process wastewater from both the electrolytic refinery and the flash furnace is sent to an on-site tailings pond.[96] At Copper Range Co.'s White Pine facility, process wastewater consists of contact and non-contact cooling water. It is commingled with mill tailings and pumped to a tailings basin where the solids settle out. The water is then discharged through permitted outfalls.[97] Approximately 4,891,000 metric tons of process wastewaters are generated annually. This waste exhibits the hazardous characteristics of toxicity (for arsenic, cadmium, lead, and mercury) and corrosivity.[98] We used best engineering judgement to determine that this waste may also exhibit the characteristics of toxicity for selenium. This waste stream is recycled and classified as spent material. Additional data are included in Attachment 1.

Scrubber blowdown. This waste results when low volumes of high total dissolved solids (TDS) materials are removed from the gas scrubbing system. At the Hidalgo smelter in Playas, NM, the scrubber had processed electric furnace dust and the wastewater was routed to the acid plants, followed by an evaporation unit. However, the system was scheduled to be taken off-line by 1993.[99] Chino Mining Company in Hurley, NM neutralizes the blowdown with magnesium hydroxide in a settler. The solids are recycled to the smelter and the fluids are recycled to the concentrator.[100] At Magma Copper company's San Manuel, AZ facility, Lurgi scrubber blowdown is usually recycled back through the concentrator. Only during mechanical failure, or insufficient mill capacity does the solution become mixed with acid plant blowdown and tailings for deposition on the tailings impoundments.[101] At Cyprus Mining Corporation, Casa Grande, AZ, scrubber blowdown resulting from tail gas cleaning operations using a double-contact alkali scrubber generates a slurry that is discharged to a 40-mil lined lagoon.[102] This waste exhibits the characteristic of toxicity for arsenic, cadmium, and selenium, and may also be toxic for mercury.[103] This waste stream is partially recycled and classified as spent material. Although no published information regarding the waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 49,000 metric tons/yr, 490,000 metric tons/yr, and 4,900,000 metric tons/yr, respectively. Additional data are included in Attachment 1.

Discarded Furnace and Converter Brick. This maintenance waste is periodically generated during rebuilding of the furnace and converters. At one facility, bricks are crushed and stockpiled for recycling to the sulfide mill where the copper is recovered through beneficiation. Furnace brick, at one location, was reported to contain 7 percent iron, 6 percent copper, 2 percent magnesium, and 1 percent phosphorus.[104] Approximately 3,000 metric tons of furnace brick is generated annually.[105] Revert (molten matte that is spilled during its transfer in the smelting process) also contains

[95] U.S. Environmental Protection Agency, 1991, Op. Cit., p. 5.

[96] RTI Survey 100750, 1989, Op. Cit.

[97] RTI Survey 101782, National Survey of Solid Wastes from Mineral Processing Facilities, Copper Range Co., White Pine, MI, 1989.

[98] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[99] RTI Survey 100487, 1989. Op. Cit.

[100] RTI Survey 100495, 1989, Op. Cit.

[101] RTI Survey 100750, 1989, Op. Cit.

[102] ICF Incorporated, Mineral Processing Waste Sampling Survey Trip Reports, Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, August 1989, p. 2.

[103] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[104] U.S. Environmental Protection Agency, 1991, Op. Cit., p. 7.

[105] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

EXHIBIT 1 (Continued)

significant conc entrations of c opper a nd is returned to the crushing/grinding circu it.[106] At one facility, the converter bricks are re-processed through the smelter while the furnace bricks are discarded. Some bricks may contain chromium above hazard ous characteristic levels.[107]

APC dusts/sludges. Generated during smelting operations, these materials may contain significant concentrations of copper. These dusts/sludges are typically fed back to the smelter.[108] Site-specific ma nagemen t information is a vailable for several companies. Magma Copper (Arizona), has constructed a new flue dust leaching (FDL) facility to recover copper from several smelter by-product streams. Feedstocks to the FDL facility include flash furnace dust (20-25 percent copper, 1.3 percent arsenic), converter flue dust (80 percent copper, 0.01 percent arsenic), acidic bleed solution from the Lurgi scrubbers (3.6 g/L copper, 0.4 g/L arsenic, 3.5 g/L acid pH 1.6).[109] At Kennecott Utah Copper, Bingham Canyon, UT, only some of the copper -containing flue d ust is returned to the smelting vess el; the major ity of the flue dust is stockpiled for future recycling.[110]

Alternatively, bismuth can be recovered from air pollution control solids. Specifically, in copper smelting, a portion of the bismuth is volatilized in the copper co nverter and caught with such elements as lead, arsenic, and antimo ny as a dust in a baghouse or cottrell system. The dust is then transferred to a lead smelting operation. A major portion of the bismuth, however, also remains with the metallic copper. Therefore, during electrolytic refining of the copper, the bismuth accumulates in the anod e slime and can be reclaim ed during recovery o perations.[111,112] Although no published information regarding w aste generatio n rate or cha racteristics was fo und, we used the method ology outline d in App endix A of this repo rt to estimate a lo w, medium, and high ann ual waste gene ration rate of 1 00 metric to ns/yr, 222,0 00 metric tons/yr, and 450,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for arsenic. This waste stream is fully recycled and classified as sludge.

Surface impoundment waste liquids. The liquids sent to surface impoundments frequently contain mixtures of tailings and process wastewater (such as slag concentrate filtrate), which may have been treated in a wastewater treatment pla nt. Often the solid s are allowed to settle out, and the liquids are d ischarged th rough pe rmitted outfalls. Approximately 615,000 metric tons of surface impoundment liquids are generated annually. This waste exhibits the hazardo us character istic of corrosiv ity.[113] We used b est engineering judgement to d etermine that this waste may also exhibit the hazardous characteristics of toxicity for arsenic, lead, and selenium. Also, we used best engineering judgement to determine that this waste stream is partially recycled. This waste is classified as spent material. Additional data are included in Attachment 1.

[106] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 11.

[107] U.S. Environmental Protection Agency, Trip Report -- Site Visit to Magma Copper and Cyprus Miami Copper Mines," Draft Memorandum, Office of Solid Waste, April 1994b.

[108] Gavin, P. Swayn, Ken R. Robilliard, and John M. Floyd, "Applying Ausmelt Processing to Complex Copper Smelter Dusts," Journal of Mines, 45, No. 8, 1993, p. 35.

[109] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 9.

[110] ICF Incorporated, 1989, Op.Cit., p. 2.

[111] "Indium and Bismuth," ASM International Materials Handbook, Tenth Edition, Vol. 2: Properties and Selection: Non-ferrous Alloys and Special-Purpose Materials, 1990, p. 753.

[112] Funsho K. Ohebuoboh, "Bismuth-Production, P roperties, and Applications," Journal of Mines, 44, No. 4, 1992. pp. 46-49.

[113] Ibid.

EXHIBIT 1 (Continued)

Non-recyclable APC dusts. APC dusts are collected by baghouses, electrostatic precipitators, and cottrell systems. If the APC dusts contain insufficient concentrations of copper or other values, the material is judged not to be economically recoverable. At Kennecott's Bingham Canyon, UT facility, the majority of its flue dust is stockpiled for future recycling.[114] Approximately 7,000 metric tons of non-recyclable APC dusts are generated annually.[115] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Chamber solids/scrubber sludge. Approximately 31,000 metric tons of chamber solids and scrubber sludges are generated annually.[116] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent black sulfuric acid sludge. This material is obtained from the vacuum evaporation of decopperized electrolyte. The black acid liquor may be also be used in leaching operations or be sold to fertilizer manufactures.[117] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

WWTP sludge. This sludge results from the neutralization of process waters using magnesium hydroxide or lime. This material is generated by both the Phelps Dodge Hurley facility, which uses magnesium hydroxide, and the Kennecott's Bingham Canyon plant, which uses lime.[118,119] Approximately 6,000 metric tons of solids and sludges are generated annually.[120] Although no published information regarding waste characteristics was found, we used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for cadmium and lead. This waste stream is partially recylced and classified as sludge. Additional data are included in Attachment 1.

Attachment 2 contains a summary of the operational history and environmental contamination documented at several former copper production sites that are now on the Superfund National Priority List.

D.   Ancillary Hazardous Wastes

Ancillary hazardous wastes may be generated at on-site laboratories and include chemicals, liquid samples, and ceramics/crucibles which are disposed of off-site at commercial hazardous waste facilities. Samples of electrolyte are recycled to the plant.[121] Other hazardous wastes may include spent paints and solvents (non-chlorinated solvents such as "140 Stoddard" and petroleum naphtha, and "Safety Kleen" solvents) generated from facility maintenance operations, spent batteries, asbestos, and polychlorinated biphenyls (PCBs) from electrical transformers. Waste oil also may be generated, and might be hazardous. Non-hazardous wastes are likely to include sanitary wastewater, power plant wastes (such as run-off from coal piles and ash), and refuse.

Finally, spent catalysts (vanadium pentoxide) are produced in the acid plant. The spent vanadium pentoxide catalyst is either sent off-site for recycling, or disposed of either on- or off-site.[122]

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[114] ICF Incorporated, 1989, Op. Cit., p. 2.

[115] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[116] Ibid.

[117] U.S. Environmental Protection Agency, 1984, Op. Cit., p. 3-12.

[118] U.S. Environmental Protection Agency, 1992, Op. Cit., p. 13-74.

[119] RTI Survey 100834, 1989, Op. Cit.

[120] U.S. Environmental Protection Agency, 1992, Op. Cit.

[121] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 308.

[122] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 12.

EXHIBIT 1 (Continued)

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EXHIBIT 1 (Continued)

ATTACHMENT

MINING SITES ON THE NATIONAL PRIORITY LIST

EXHIBIT 1 (Continued)

Mining Sites on the National Priority List

Name of Site:	Anaconda Smelter
Owner of Site:	Anaconda Copper Mining Company (merged with ARCO in 1977)
Location of Site:	Mill Creek, Montana (26 miles west of Butte)
Climate Data:	To be determined
Commodity Mined:	Copper

Facility History: The Anaconda Copper Mining Company first began copper smelting operations in 1884 at the "Upper Works" smelter. The Upper Works consisted of a concentrator and smelter buildings, which housed roasters and reverberatory furnaces, all connected to masonry flues and two smokestacks. By 1887, the company had expanded and built an additional smelter 1 mile east of the Upper Works. The new smelter was known as the "Lower Works". By 1889, an electrolytic copper refinery had been built as well, and was located between the two smelters. Due to shortage of smelting capacity, a larger, more efficient copper smelter was completed in 1902, and known as "Smelter Hill" or "Washoe Smelter". The Upper and Lower Works were subsequently demolished in 1903. The Washoe Smelter operated from 1902 to 1980.

Waste(s) at Issue: Copper ore processing has produced wastes that cover over 6,000 acres and contain elevated levels of arsenic, cadmium, copper, lead, and zinc. Wastes include 185 million cubic yards of tailings (pond); 27 million cubic yards of granulated slag (pile); and 0.25 million cubic yards of flue dust. Stack emissions have contaminated the soils near the smelter. Ongoing fugitive flue dust emissions (from piles) and fugitive dust emissions (from soil) have contaminated the community for over 100 years.

Disposal Sites: This site has 12 Operable Units, but only two have been investigated:
Mill Creek Operable Unit — Mill Creek is an unincorporated community located approximately 25 miles west-northwest of Butte, Montana. It covers 160 acres of land and consists of 37 household with less than 100 people. The contaminants of concern in this Operable Unit are arsenic, lead, and cadmium. Arsenic dust in the air, and arsenic, lead, and cadmium in the soil and drinking water present public health risks.
Flue Dust Operable Unit — flue dust is a fine grained waste material which was formed in the smelter flue. The dust contains high concentrations of arsenic, cadmium, copper, lead, and other metals. The amount of flue dust stored onsite, as of December 1989, was estimated to exceed 316,000 tons.
The other 10 Operable Units are as follows: Smelter Hill — former ore processing area. This Operable Unit has soil and ground water contamination by metals. Old Works — Wastes (tailings) are located in a 100-year floodplain along a 2.75 mile stretch of Warm Springs Creek. This area is the focus of a removal operation. In addition, waste piles and soils at the smelter site and surface water near the site will be sampled. Arbiter — a copper refining plant that produced cathode copper from sulfide ores using an ammonia leach process. Slurry wastes from this inactive plant contain arsenic, cadmium, lead, zinc, and are located in a pond near the plant. Beryllium Disposal Areas — a beryllium flake-metal pilot plant and a beryllium oxide pilot plant were operated on Smelter Hill between 1964 and 1968. Following closure, waste containing beryllium was disposed of in the Opportunity tailings pond. Community soils — nearby community soils contaminated by smelter emissions. Slag — slag is the material separated from the metal during refining process; it consists of 85% silica dioxide (sand) and 15% iron oxide.
Tailings/Alluvium — tailings make up the largest volume of waste at this site and are deposited in both the Anaconda and Opportunity ponds. The Opportunity ponds stretch 3 miles across from east to west. Regional Soils — contaminated agricultural lands surrounding the site. Regional Ground Water — ground water

EXHIBIT 1 (Continued)

which have been contaminated from sources such as the Opportunity ponds, slag piles, tailings, and contaminated soils. <u>Surface water and sediment</u> — tailings have migrated into streams near the site.

Soil Pathway: It was discovered that the soil contamination (by arsenic, cadmium, and lead) in Mill Creek was widespread. The geometric mean concentration of arsenic in Mill Creek surface soils is 638 mg/kg; for cadmium it is 25 mg/kg; and for lead it is 508 mg/kg. At a depth of 18 inches, concentrations of arsenic are below 100 mg/kg and approach background levels at 42 inches below the surface. High concentrations of cadmium and lead are also found in the first 6 inches of the soil profile. However, lead and cadmium concentrations decrease more rapidly with depth than arsenic concentrations. Cadmium levels were found to be less than detection limits at a depth of 9 inches, and lead levels reached background levels below 6 inches.

Ground Water Pathway: The water table underlying Mill Creek is 20 feet or deeper below the surface. Domestic well water is drawn from this aquifer. In 1986, sampling showed that seven household water supplies had detectable arsenic levels. Cadmium and lead levels were mostly at or below detection limits.

Surface Water Pathway: Mill Creek is the major drainage system is the area of the Anaconda Smelter and the Mill Creek community. Mill Creek was sampled four times and results showed that arsenic was present in the creek. Total arsenic concentrations ranged form 12 to 32.2 ug/l. Zinc was also detected in the waters of Mill Creek. Until transport of contaminated soil into Mill Creek is controlled or remedied, it is estimated that recontamination of Mill Creek will occur at a rate of 1.5 mg/kg of soil per year.

Air Pathway: In 1984, samples of airborne particulate matter were collected at four different locations near the smelter and tested for total suspended particulates, respirable particulates, and trace-metal content. Arsenic concentrations were found to be 0.1 mg/m^3. The highest arsenic concentration found at the Mill Creek station was 0.681 mg/m^3. Elevated levels of cadmium, lead, and arsenic were found in household dust samples as well. Residential dust showed an average concentration of 264 mg/kg arsenic, and indoor respirable arsenic concentrations were 0.019 ug/m^3.

Environmental Issues: The Anaconda Smelter site is located in the Upper Clark Fork Basin above Warm Springs Creek and the main stem of the Clark Fork River to the Bitterroot River below Missoula, Montana. In addition, the community of Mill Creek is immediately adjacent to this site. Therefore, contaminants from the Anaconda Smelter site (e.g., arsenic, lead) pose a potential risk to human health and the environment (e.g, aquatic life, drinking water).

EXHIBIT 1 (Continued)

Mining Sites on the National Priority List

Name of Site:	Tex Tin Corporation
Owner of Site:	Tex Tin Corporation
Location of Site:	Texas City, TX (situated on 175 acres in an area of mixed land use)
Climate Data:	Not given
Commodity Processed:	Secondary copper smelting
Facility History:	Originally operated by the U.S. Government during World Ward II as its primary tin smelting operation, the site was then acquired by the Associated Metals and Minerals Corporation from the Wah Chang Corporation in 1970 and became know as the Gulf Chemical and Metallurgical Company (GC&M). Since 1985, the company has been known as the Tex Tin Corporation. At one time, the facility was operated as an iron recovery facility, but it is currently engaged in the secondary smelting of copper. The Tex Tin site was added to the NPL in August 1990.
Waste(s) at Issue:	Heavy metals (arsenic, tin, lead and nickel) found in onsite surface and ground water, and in ambient air sampled on and off the site.
Disposal Site:	In 1977, the Tex Tin had three metals reclamation circuits: nickel sulfate, ferric chloride, and tin. <u>Nickel sludge circuit</u> - The nickel sludge was stored in drums in the north end of the smelter building. After smelting, waste sludge was sold for other metals recovery. A small quantity removed during vessel cleaning was dumped with the slag from the tin process. <u>Ferric chloride circuit</u> - The company was sold iron sludge contaminated with the herbicide Amiben. The material was stored in two areas (not specified). Runoff would flow through the plant to the pond system. A small quantity removed from the settling tank was disposed of in Acid Pond B. <u>Tin ingots circuit</u> - The product was received in the form of ore sacks (imported from Bolivia) which were stored on pallets by Ponds A and B, tin residues in 55-gallon drums which were stored in the ore storage building, and tin ore which were piled along Highway 519. After primary smelting, rich slag was stored onsite. End slag was produced after the electrolyte process and GC&M planned to install a new rotary furnace for secondary tin smelting. In 1979, the nickel circuit had been discontinued. Ferric chloride production had also decreased which caused GC&M to cease buying Amiben-contaminated iron sludge for use in this circuit. GC&M also stopped disposing of the settling-tank sludge in the acid pond. A rotary furnace was added to the tin circuit which resulted in material dumped north of the acid pond. Waste areas identified at the site have included wastewater treatment ponds, a gypsum slurry pond, an acid pond which once contained ferric chloride and hydrochloric acid, several drained acid ponds, slag, sludge, and ore piles. One of the slag piles is contaminated with the herbicide Amiben. The facility also stored approximately 4,000 drums containing radioactive material. At one time, the facility stored piles of spent catalyst in the anticipation of building a plant to extract metals such as tungsten. An inactive, licensed, low-level radioactive landfill, containing uranium/antimony slag, is also located onsite. The slag is from a pilot study on the extraction of bismuth from a bismuth-uranium catalyst. One other area of possible contamination, an abandoned oil-processing facility, has been identified on the Tex Tin property. The Morchem Resources facility was located on the northwestern portion of the site (then owned by GC&M) from 1982 to 1983. Morchem processed Luwa bottoms (high boiling-point glycols with 1% molybdenum) and waste oil from chemical and refining companies. The facility was abandoned in 1984. No other information is known about this facility.
Soil Pathway:	Possible soil contamination is not well characterized. In 1980, EPA conducted a Potential Hazardous Waste Site Inspection. Piles of tin slag, iron ore, and crushed empty barrels were noted in the rear of the plant. A reddish material (possibly iron) was noted in the drainage ditch located close to the area of the material piles. One

EXHIBIT 1 (Continued)

soil sample was collected by the Texas Department of Health's Bureau of Radiation Control near the low-level radioactive landfill in December 1984. The four metals detected were found to be at significantly elevated concentrations and considered a health concern. They include: antimony (2,590 ppm), arsenic (720 ppm), copper (130 ppm), and lead (980 ppm). The level of copper in the soil was not sufficiently elevated to represent a health concern.

Ground Water Pathway:

The Chicot Aquifer underlies the site and extends from 60 feet to approximately 1,000 feet below the land surface. The flow is generally in a southeasterly direction towards Galveston Bay. Ground water in the vicinity of the acid pond was monitored from 1975 to 1980. The monitoring wells were screened at 37 to 47 feet below the ground surface. The contaminant concentrations detected were much higher from the downgradient wells' samples as compared to the upgradient well. Twelve metals were detected and determined to exceed drinking-water standards and long-term health advisories. The metals of concern and their maximum concentrations detected include: arsenic (0.198 ppm), barium (6.5 ppm), cadmium (7 ppm), chromium (0.25 ppm), copper (390 ppm), lead (200 ppm), manganese (357 ppm), mercury (0.011 ppm), nickel (7 ppm), silver (1.02 ppm), tin (100 ppm), zinc (140 ppm).

Surface Water Pathway:

Inspections by the Texas Water Quality Board concluded that dikes designed to prevent discharges from two old outfalls and the acid pond were seeping, allowing contaminated water to enter Wah Chang Ditch. The ditch is currently pumped into the Texas City Industrial Channel, which enters Galveston Bay. Twelve surface water samples were collected from various locations at the facility between 1975 to 1988. The constituent of concern and their maximum detected levels include: arsenic (0.94 ppm), chromium (81 ppm), copper (60 ppm), mercury (0.02 ppm), nickel (535 ppm), zinc (42.7 ppm).

Air Pathway:

In January 1986, air-quality monitoring samples were obtained along the site perimeter using high-volume particulate samplers. The conclusion reached after the sampling was that heavy metals and arsenic were being carried offsite by the wind. The maximum values of the detected contaminants were: arsenic ($2.34 \ \text{ug/m}^3$), cadmium ($0.64 \ \text{ug/m}^3$), chromium ($0.40 \ \text{ug/m}^3$), lead ($4.42 \ \text{ug/m}^3$), nickel ($0.21 \ \text{ug/m}^3$), and tin ($103.6 \ \text{ug/m}^3$).

Environmental Issues:

Commercial businesses, residential areas, and petrochemical complexes are all located within 0.25 miles of the site. The saline Swan Lake is located approximately 2 miles from the site and is used primarily for recreational fishing and crabbing. A principal concern is the potential environmental contamination of surface waters through the transport of heavy metals into Chicot Aquifer, and drainage of contaminated water into Galveston Bay. Most drinking water is supplied municipally, however, a 1985 survey identified a small beach house community located approximately one mile southwest of the Tex Tin facility that uses private water wells. The community, consisting of approximately 60 homes, is supplied by 25 wells. While most of the wells are more than 200 feet deep, at least three of the wells are less than 105 feet deep and are in the Chicot Aquifer. Possible human routes of exposure were noted as ingestion, inhalation, and dermal contact with contaminated media. Inhalation and incidental ingestion of airborne particles of Tex Tin emissions or entrained dust have also been cited as potential pathways of concern. In addition, low levels of radioactivity have been detected onsite in association with the tin, copper, and antimony slags and with the company roads that have been graded with tin slag. According to the Bureau of Radiation Control, the radiation levels are well below Federal occupational exposure limits, but are approaching the upper limits of the range of levels generally considered safe for the general public.

EXHIBIT 1 (Continued)

Mining Sites on the National Priority List

Name of Site:	Torch Lake
Owner of Site:	Not applicable
Location of Site:	Keweenaw Peninsula of Upper Michigan (14 miles from Lake Superior)
Climate Data:	Not given
Commodity Mined:	Copper

Facility History:
For over 100 years, the area surrounding Torch Lake was the center of Michigan's copper mining, smelting, and milling activities. Over 10.5 billion pounds of copper were processed in the area between 1868 and 1968. An estimated 5 million tons of copper were produced in the Keweenaw Copper District of Michigan from the 1960's to 1968. More than half of this was processed along the shores of Torch Lake. Mining activities in the lake area peaked between the early 1900's and 1920. By 1986, only one small copper recovery plant was still operating. Torch Lake was listed on the NPL in June 1988.

Waste(s) at Issue:
At the mills, copper was processed and the recovered copper was sent to a smelter, while tailings were disposed of with process wastewaters into or on land around Torch Lake. In 1916, copper was recovered from previously discarded tailings in Torch Lake through an ammonia leaching process. Further technological advances initiated a flotation process using reagents consisting of 50 percent coal tar, 15 percent pyridine oil, 20 percent coal tar creosote, and 15 percent wood creosote. In 1926, xanthates were added to the reagents. Between 1868 and 1968, an estimated 200 million tons of tailings were pumped into the lake, reducing its volume by approximately 20 percent.

Disposal Site:
The Torch Lake site has three operable units (OUs). OU1 includes surface tailings, contents of buried and submerged drums along the western shore of the lake, and industrial chemicals. OU2 includes potentially contaminated media in and around the lake. OU3 includes other tailings sources in the mid-Keweenaw Peninsula, including the North Entry, the northern portion of Portage Lake, and tributary areas.

Tailings:
Mine tailings are divided into two categories. The first involves tailings resulting from crushing and gravitational separation processes. The resulting contaminants of concern are: aresenic, copper, lead, and zinc. The second category of tailings is a result of flotation reprocessing. The contaminants of concern associated with this category include: arsenic, copper, lead, zinc, and industrial chemicals (lime, pyridine oil, coal tar creosotes, wood creosote, pine oil, and exanthates). Surface and subsurface tailings samples were collected and analyzed. Fifty eight surface samples were collected from a 0- to 6-inch depth and density of 1 sample per 10 acres. Twelve subsurface samples were collected from a depth of 0 to 3 feet and at a density of 1 sample per 20 acres. The sampling analysis indicated that the concentration and distribution of metals appeared to be similar in both surface and subsurface samples. Copper concentrations were elevated above background soil concentrations (3,020 mg/kg surface and 5,540 mg/kg subsurface as compared to 100 mg/kg in native soils). In summary, however, neither organic or inorganic compound levels in tailings from OU1 were found to be dramatically higher than background soils. In 1989, the U.S. Bureau of Mines determined that leachate from Torch Lake mine tailings was extremely low in comparison to leachate from 30 other sites and they concluded that very little metal is being released from the tailings.

Drums:
In 1989, buried and submerged drums in tailings piles were discovered and determined to have very low hazardous constituent concentrations as measured by EP Toxicity tests. PCBs and pesticides were not found above the detection limits in

EXHIBIT 1 (Continued)

the samples. The eighth drum contained 4,000 ppm of trichloroethylene; and it is suspected that the contents of the drum are related to illegal dumping.

Soil Pathway: A limited soil investigation found that traces of tailings and slag were evident. The contaminants of potential concern and their maximum values detected include: aluminum (7,600 mg/kg), arsenic (7 mg/kg), barium (101 mg/kg), chromium (20.1 mg/kg), copper (459 mg/kg), lead (329 mg/kg), manganese (357 mg/kg), mercury (0.47 mg/kg), nickel (33.7 mg/kg), and vanadium (26.30 mg/kg). Soil samples from residential locations generally had concentrations of inorganic compounds an order of magnitude higher than background concentrations. The EPA Technical Assistance Team (TAT) also collected samples from the east side of Torch Lake and determined that the metals detected in the samples were all within typical soil background concentrations and below maximum concentrations for EP Toxicity.

Ground Water Pathway: The U.S. Geological Survey sampled well water in 1968 and 1977. Analysis of the 35 wells in Houghton County indicated that only 3 had specific conductance greater than 500 micromhos per centimeter. These results indicated Torch Lake as a high quality water source for general use. Many Torch Lake communities and seasonal residents get their water from municipal systems or from an independent supplier. In July 1989, EPA's TAT sampled seven private wells and two municipal wells. Only one location sampled had a concentration of either organic or inorganic compounds in excess of the Maximum Contaminant Levels (MCLs). The sample collected from the Lake Linden municipal well had an iron concentration of 0.33 ppm which is slightly greater than the Secondary MCL of 0.3 ppm for iron. Ground water contamination is to be discussed further in the ROD for OU2.

Surface Water Pathway: Water enters Torch Lake from the Trap Rock River, and Hammell, Dover, McCallum, and Sawmill Creeks. The Trap Rock River is the largest discharger into Torch Lake, and the Trap Rock River Watershed covers approximately 58 percent of the Torch Lake Drainage Basin. An estimated 2,000 kilograms per year of dissolved copper is transported through Trap Rock River and its tributaries into Torch Lake. Contamination of the surface water is to be addressed in the ROD for OU2.

Air Pathway: The Michigan Department of Resources (MDNR) collected air samples from four sampling locations (based on wind and population profiles) to monitor likely exposure points, emissions sources, and background conditions. Total Suspended Particulates (TSP) samples were collected for one month, for 24-hour periods every other day in 1989. Further analysis of the two samples indicating the highest concentration of TSP were further analyzed for arsenic, chromium, copper, nickel, lead, and zinc. The analysis indicated that mean ambient-air concentrations at the two sample stations exceeded background ambient-air concentrations for aluminum, arsenic, barium, copper, magnesium, iron, manganese, and TSP.

Environmental Issues: A century of mining waste deposition into Torch Lake created environmental concerns in the 1970's. In 1971, a discharge of cupric ammonium carbonate leaching liquor from the Lake Linden Leaching Plant occurred and MDNR reported discoloration of several acres of lake bottom. Further investigations found 15 water quality parameters with acceptable background ranges. Heavy metal concentrations in lake sediments were within background ranges, except for arsenic, chromium, zinc, and copper, which were all at elevated levels. Plant and benthic invertebrate analysis did not indicate any water quality changes. Three months later, the spill was cited as the cause of temporary depletion of oxygen, elevated copper levels, increased pH, and increased carbon alkalinity in the lake and bioassays indicated toxicity to some macroinvertebrates. Changes in the dominant predator fish species and observance of abnormalities in certain fish species prompted a fish consumption advisory in 1983 for Sauger and Walleye caught in the lake. In the same year, the lake was designated as a Great Lakes Area of Concern (AOC). In 1988, the Agency for Toxic Substances and Disease Registry (ATSCR) concluded that the site is a potential public health concern because of possible exposure to unknown etiological agents that may create adverse health effects over time. The mine tailings contaminating Torch Lake have not been determined to cause known health effects,

EXHIBIT 1 (Continued)

and there is no indication that human exposure is currently occurring or has occurred in the past.