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Mine the Gap: Connecting Water Risks and Disclosure in the Mining Sector

MARTA MIRANDA and AMANDA SAUER with contributions by DEEPA SHINDE

Water issues are becoming a considerable factor affecting growth and profitability of companies in many regions of the world. This paper outlines potential water-related risks facing the mining industry and highlights important gaps in water-related disclosure. The purpose is to provide information, questions, and tools to help the financial community better evaluate water-related risks facing mining companies.

This research focuses on global hardrock minerals operations and does not cover industrial or fuel minerals.

Marta Miranda is the Principal of Terra Business & Environment Strategies. martajlmiranda@gmail.com

Amanda Sauer is a Senior Associate at WRI. asauer@wri.org

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KEY FINDINGS

Water risks span the minerals production cycle and occur in diverse operating environments.

- **Water quality problems** are among the most serious environmental impacts associated with mining. Toxic waste and mine effluents can be mobilized by water, resulting in regulatory, legal, and reputational risks for companies.
- **Work stoppages or mine shut downs** can occur if water resources become unavailable. Mining—particularly for precious metals, diamonds, copper, and nickel— requires significant volumes of water.

Mining companies have long been conscious of water risks, as evidenced by their ongoing efforts to address them and related corporate reporting. Indeed, recent analysis has shown that the mining sector is a leader in terms of water reporting.[1] However, **corporate disclosure often does not provide a comprehensive picture of water risk**. Current reporting frameworks do not guide companies to disclose the full scope of potential water risks.

- **Water quality data is not sufficiently reported.** Data on water effluents and waste management practices are either not reported or not detailed enough to understand risk. The impact of mining activities on other water users is also rarely reported.
- **Water consumption data lacks context.** All water is local, thus water usage data is only relevant when placed in the context of local water availability. Competing demands from communities, agriculture, and other industrial users must be factored into assessments of local water availability.
- **Water reporting is not consistent**. Most Asian mining companies report little or no water-related information, even though Chinese and Indian companies account for an increasingly significant share of mining equities and may face serious water constraints. Companies that do report water-related metrics use different approaches to calculating and reporting data, making it difficult to compare performance across companies.

The financial community does not currently have adequate information about the water risks facing mining companies. This paper aims to address this problem by explaining how water issues and trends may create potentially costly water-related risk for companies (Section I) and by providing tools, questions, and information to help the financial community better evaluate water risks in the mining sector (Section II).

Section I: Water Risk in the Mining Sector

1.1. WATER-RELATED ISSUES IN MINING

The mining sector is a significant water user and producer of wastewater.[2] In most countries, the mining industry is a relatively small water user compared to agriculture or other industries. For example, mining accounts for about 1 percent of freshwater withdrawals in the United States.[3] However, a mining operation may be the largest water user within a particular watershed (especially of groundwater resources) and therefore may impact the availability of water for other purposes. In addition to direct water consumption, the mining industry can have significant impacts on the quality of local water resources. As a result, mining operations can impact local communities and ecosystems by affecting water supplies.

Water-related issues can arise at nearly every stage of the mining process. See Table 1. The most serious water issues in mining occur in conjunction with toxic waste disposal and as a result of water consumption at the extraction and processing phases. (See Appendix I for an overview of the mineral development process and Appendix II for more information on the broader environmental impacts of mining). Water issues can generally be divided into *water availability* and *water quality* concerns.

Water Availability

Mining requires significant volumes of water, especially in the extraction and processing phases. For example, on average it takes 716 cubic meters of water to produce a tonne of gold.[4] Most water at the mine site is used to grind and separate minerals from host rocks, to wash and transport materials, to control dust, and to cool drilling machinery.[5] Water consumption varies greatly depending on a range of factors including climate conditions, ore mineralogy, mine management and practices, and the commodity being mined.

Table 1: Summary of Water-Related Issues at Different Mining Stages

Stage	Potential Issues
Exploration/site preparation (surveying, drilling, trench blasting, camp and road construction, mine construction)	• Sediment runoff, increased suspended sediment load to surface waters • Spills of fuels and other contaminants
Mineral extraction (blasting, ore stockpiling, waste piling)	• Chemical contamination of surface and ground waters • Toxicity impacts to organisms (terrestrial and aquatic plants and animals) • Altered landscapes from mine workings (e.g., open pits, changes in stream morphology) • Increased erosion and siltation • Altered patterns of drainage and runoff • Water consumption: dust suppression, mine camps, evaporative losses from clean water storage dams, water used to cool equipment • Decreased groundwater resources due to dewatering pits • Reliance on power from water-dependent sources (hydro and thermal)
Processing (mining, smelting, refining)	• Discharge of chemicals and other wastes to surface waters • Water consumption: water used in mineral separation and benefication, slurry lines • Reliance on power from water-dependent sources (hydro and thermal)
Product transport (packaging, transport)	• Water consumption: water added to ore concentrates to facilitate transport
Mine-closure/post-operation (revegetation, fencing, monitoring seepage)	• Persistent contaminants in surface and groundwaters • Expensive, long-term water treatment • Persistent toxicity to organisms • Permanent landscape changes

Source: Adapted from Miranda et al. 2003. *Mining and Critical Ecosystems: Mapping the Risks*. World Resources Institute, Washington, DC.

Even within a particular commodity there is great variation in water use. In general, gold, platinum, diamonds, nickel, and copper are associated with the highest water consumption.[6] This occurs because precious metals and minerals are often associated with low ore grades, meaning that low concentrations of ore embodied in waste rock require greater water and energy usage to separate the ore from the rock. Unsurprisingly, arid and semi-arid regions pose greatest water availability challenges for mining companies.

Desalination provides one potential alternative to freshwater withdrawals and is used in certain regions of the world, notably in northern Chile. However, water desalination plants are expensive to construct and operate. In Chile, investment in desalination plants is projected to cost between $100 million for small mines to $3.5 billion for large copper projects.[7] Desalination also has significant energy requirements, requiring 3 - 10 kWh per cubic meter of water produced and costing $1.8 - $2 per cubic meter of desalinated water in Chile.[8,9] Furthermore, reductions in freshwater use as a result of desalination can increase greenhouse gas emissions if fossil fuel derived power is used. Therefore improvements in freshwater consumption may come at the expense of energy and climate change concerns.

Water Quality

Water quality concerns are among the most severe environmental impacts associated with mining. Toxic waste and mine effluents can be mobilized by water, resulting in a substantial decline in local and sometimes regional water quality. One of the most serious environmental impacts from mining is acid drainage, which can occur when sulfide bearing rock is exposed to water or air, leaching heavy metals and polluting nearby water bodies. Excessively humid environments exacerbate the challenges for managing water quality.

Acid drainage, spills, and other water quality concerns can have significant impacts on ecosystems and local communities. Contaminated water caused by mine effluents can pose serious risks to human health and economic welfare. Toxic materials from hardrock mines that get into surface and ground water and soil can lead to declines in fish and crop yields. Furthermore, the metals in contaminated water can harm humans who consume affected drinking water, animals, and plants. Direct impacts on human health include serious conditions such as respiratory disorders, genetic mutations, birth defects, tumors, and cancers.[10]

Contaminated water can originate from:

- **Waste rock**: rock that is deemed unsuitable for processing is usually piled up near the open pit and if left uncovered, may be a source of acid drainage.
- **Ore stockpiles**: piles of material containing lower quantities of the target metal are usually stockpiled for future processing and may be a source of acid drainage if left uncovered.
- **Pit walls**: an increased surface area of potentially sulfide-bearing rock can be exposed through construction of an open pit, creating additional opportunities for acid drainage.
- **Tailings impoundments**: tailings from the mining processing phase are typically pumped as a thick sludge to a large impoundment. Depending upon the moisture content of the tailings and waste management practices, toxic materials can leach into groundwater. In addition, major storm events can mobilize tailings, rupturing the dam and causing toxic releases into nearby streams.
- **Tailings pipes**: in some cases, mines may release contaminated water in a controlled or uncontrolled manner into nearby streams. Some sites in New Guinea are designed to release tailings directly into rivers (i.e., riverine tailings disposal).
- **Raw sewage**: accidental or deliberate releases of untreated sewage from mine camps may contaminate surface waters.
- **Abandoned pits and mine workings**: acid drainage may continue long after mine closure, especially if the site was abandoned, or waste piles and pits were not properly sealed.

While regulators and mine managers recognize the importance of minimizing water use and containing mine wastes, water contamination remains one of the most common environmental impacts associated with mining.[11] Furthermore, water quality problems are usually not identified or predicted in the environmental impact assessment (EIA) required prior to mine development: A two year research study on the accuracy of water quality predictions at hardrock mines in the U.S. found that although none of the EIAs prepared for these mines predicted water quality problems, 76 percent of the sites polluted ground or surface waters in excess of water quality standards. Furthermore, nearly all (93 percent) of the sites with acid drainage problems had not anticipated this risk in their EIAs.[12]

1.2. WATER-RELATED TRENDS IN MINING

Water availability and quality issues are likely to increase due to the following trends:

- **Rising global demand for mineral and metal commodities will increase the industry's impact on water resources**. The scale of modern mining is expanding across the globe. Mining projects are typically designed to achieve large ore throughput and therefore generate substantial quantities of waste that need to be managed in order to prevent contamination of local water sources.[13] The sheer increase in the number and the size of future mining waste sites will require significant public and private sector oversight that extends well beyond the operable life of the mine.

- **Mining activities are increasingly taking place in countries facing growing water challenges.** North America, Australia, Chile, and South Africa have traditionally dominated global mineral production, with operations often located in water scarce regions. While Australia remains a mining powerhouse, in recent years, the production of major mineral commodities has been shifting toward developing countries (see Appendix III). Asian countries—especially China and India—are ranked among the top three largest producers of most non-fuel minerals.[14] Many regions of China and India are considered to be water stressed and face demographic and economic trends that will intensify competition for water resources. While water-related conflicts can occur in any water scarce region, such events may be exacerbated by limited water infrastructure and less stringent water quality regulations that are more likely to affect operations in emerging economies.

- **Globally declining ore grades for many major commodities are likely to increase water demands for most future mines**.[15] The ore grades of most mineral commodities are in decline, particularly for precious metals. [16] Low ore grades do not contain a high proportion of valuable metal and minerals to waste rock. This means that each unit of production results in greater quantities of waste and higher water and energy consumption. While technological and process advancements may mitigate these increases to some extent as established companies employ water recycling technologies, it is likely that the extractive industries will depend on greater water use in the years to come.[17]

- **Climate change impacts are expected to increase water-related issues in many metal and mineral rich regions.** Arid and semi-arid production regions will be most affected by water shortages, although flooding will likely create problems in water-rich areas. Less rainfall and declining water renewals from glaciers or mountain snowpack are expected to impact India and Chile;[18,19] China and South Africa are predicted to receive decreased precipitation;[20,21] Australia and the Western United States are projected to experience more serious and frequent droughts;[22] and Indonesia and Brazil are likely to remain water abundant but may face more frequent and severe flooding.[23] While this paper provides general observations about global climate change impacts, an understanding of more precise consequences on water resources requires data at the local level. The actual impacts of climate change on water quantity and quality for mining operations will vary greatly within a country or even a watershed.

- **Mining companies based in emerging Asian economies are increasingly significant yet their water-related disclosure may be limited or lacking.** Although the largest mining companies are still based in industrialized countries, corporations headquartered in emerging economies have come to prominence in recent years. One third of the world's top 100 mining equities ranked by value are headquartered in China, India, and Indonesia.[24] Water disclosure from major companies in emerging economies varies widely, however most Asian mining companies report little or no water-related information. See Section 2.2 and Appendix V for further information on corporate water disclosure in the mining industry.

1.3. WATER-RELATED RISKS IN MINING

Water availability and water quality issues have the potential to financially impact company performance. In general, water-related risks can be broadly classified into the following categories:

- Physical Risks
- Regulatory and Legal Risks
- Reputational Risks

Physical risks are usually tied to water availability issues, while regulatory, legal, and reputational risks can stem from either water availability or water quality concerns.

Physical Risks

Given the high water demands of mining, companies may find that a lack of available water creates challenges in maintaining production. Demand for water in arid and semi-arid regions could result in work stoppages or mine shut downs if water resources become unavailable, resulting in revenue losses from lost production, high prices for emergency water supplies, and potential loss in market share due to unreliability of product supply.[25] Chile's copper industry, for example, is particularly affected by water scarcity concerns. A copper industry report released in 2009 projected that water consumption by the mining industry would increase by 45 percent by 2020.[26] Water demand in the country—of which mining is the largest industrial component —is six times greater than water renewals.[27] In Chile's arid north, mining threatens to deplete groundwater resources, which could ultimately result in the collapse of copper production—one of Chile's chief exports.[28]

Water shortages can lead to power outages, especially in operations dependent on hydroelectric power to maintain operations. Most thermal power is also dependent on steady supplies of water for cooling purposes. Low water reserves can lead to reduced power output or outages and force shutdowns at affected mining operations. For example, Rio Tinto was forced to cut output by 5 percent at its New Zealand smelter due to power outages caused by a drought in 2008.[29]

In addition, low quality water can also lead to losses in mineral recovery or reduce the product's quality. Poor quality products can become less attractive to the market and in some cases may not comply with regulatory standards (including REACH in the European Union).[30]

Regulatory and Legal Risks

Water shortages can be regulatory in nature if rules about water access or restrictions change. Water scarcity concerns may lead to increased regulation and reduced water rights for the sector. In response to the physical shortages of water threatening Chile's arid north, Chilean authorities are strictly allocating fresh-water rights among companies and closely monitoring usage of water. In one example the country's third-largest copper mine, Xstrata's Collahuasi operation, was asked to reduce its rate of water extraction to 300 liters a second from 750 litres by 2010.[31] Such reductions in water allocations may require investments in water efficiency and supply measures and/or production cuts.

Water quality problems are particularly acute in the mining sector and can result in additional operational and capital expenditures to prevent and treat contaminated waters, as well as production losses in cases where mining activities are suspended or shut down. Acid drainage is the most widespread water pollution issue and can impact water quality as a result of mining any sulfide or pyrite-bearing ore body, most prevalent in gold, copper, zinc, lead, and coal mines. According to the International Network for Acid Prevention (INAP), mines with acid drainage problems may face clean-up costs of tens and even hundreds of millions of dollars if the acid-generating material has not been properly managed and contained.[32] In addition to acid drainage issues, acid or other toxic materials may also be released into water systems either through short-term spills or longer-term leaks.

In a recent example of an accidental spill, Zijin Mining Group was forced to shut down its Zijinshan copper smelter in Shanghang after 2.4 million gallons of acidic copper was spilled into the Ting River on July 3, 2010. The toxic pollution killed 2,000 metric tons of fish, enough to feed 72,000 residents for one year.[33] The company is currently undergoing extensive investigation by the government and it is unknown when the smelter will be permitted to reopen. The financial impacts of the event are likely to be significant as output at the smelter accounts for 15 percent of Zijin's total production.[34]

Companies are responsible for complying with regulations to prevent and treat water pollution even after the mine is no longer operational. It is expensive to properly anticipate and manage closure liabilities. Newmont Mining has estimated its total closure liability to be in the hundreds of millions of dollars, of which two thirds is attributed to waste management. Much of this has been allocated to preventing and treating acid drainage into local water resources at its facilities.[35] However the costlier problem is when such liabilities are not properly managed. In some cases in the United States, clean-up costs from acid drainage have already caused smaller and medium sized companies to declare bankruptcy, leaving taxpayers to pay for clean-up costs. For example, Galactic Resources in Colorado had to declare bankruptcy and abandon its Summitville mine in 1992 because it could not afford to clean up a massive spill of toxic mine waste. The waste was dumped into the headwaters of the Alamosa River, causing a massive fish kill and pollution of streams used to irrigate nearby ranches and farms.[36]

Tightened regulations resulting from mining-related pollution incidents have had a wide-reaching effect on the mining industry. Water pollution incidents can spur new restrictions and regulations for the mining industry. As a result, responsible mining companies have an interest in encouraging good practices to prevent tightened regulatory reactions that affect all companies in the sector.

In one example, the Baia Mare incident in Romania—when a tailing spill into the Lupes, Somes, and Tisza Rivers contaminated drinking water for 2.5 million people and resulted in massive fish kill—prompted the European Union to pass and enforce stringent mine safety and waste disposal requirements.[37] In December 2009, the Hungarian Parliament passed a law banning the use of cyanide in mining. Similar referenda are being considered in the EU parliament, which passed a resolution in May 2010 proposing a complete ban on the use of cyanide mining technologies in the EU before the end of 2011.[38] If passed, these measures could put an end to much of the industrial-scale gold mining in Europe, which accounts for approximately 1 percent of global production.[39]

Such events would not be the first time water pollution from mining resulted in more stringent regulations. In 1998, the citizens of Montana passed a ballot initiative calling for a ban on the use of cyanide in heap leach mining after residents suffered repeated losses from contaminated ground and surface waters. Initiative 137 (I-137) passed by a 53 percent majority and calls for phasing out open pit, cyanide leach mining in Montana. The law has survived numerous legal challenges by the mining industry, including an appeal to the US Supreme Court in 2008.[40] [41]

Beyond regulatory compliance costs, mining companies responsible for water contamination face legal risks from affected communities. Mining companies have been found legally and financially responsible for providing restitution to local communities affected by mine-related pollution. For example in 1996, BHP Billiton reached an out-of-court settlement with villagers living along the Fly River in Papua New Guinea. According to the agreement, the company paid nearly $50 million to compensate for the contamination of local water sources with tailings and mine waste from the Ok Tedi mine.[42] In light of its experience, the company vowed never to develop another mine requiring riverine tailings disposal and to date has honored this commitment. The Ok Tedi mine continues to operate under management by a government-run company (Ok Tedi Mining Limited) and not BHP.

In another high profile case, 151 kilograms of elemental mercury was spilled by a transport contractor of Newmont's Yanacocha mine near the town of Choropampa and two neighboring villages in Peru. Approximately 900 people claimed compensation from Newmont.[43] The Peruvian government fined Newmont Mining $500,000. The company says it has paid $18 million more. Furthermore, a class action lawsuit was filed against Newmont on behalf of 1,000 residents near the mine and the case was settled in April 2009.[44] [45]

Reputational Risks

Major mining-related impacts on water resources have damaged companies' reputations, disrupting operations and losing access to future reserves. Most reputational damage for mining companies stems from water quality problems, however in arid and semi-arid regions, water withdrawals can also exacerbate competition for scarce water resources and create community opposition. A history of pollution incidents at Newmont's Yanacocha mine created local unrest and ultimately resulted in work stoppages. As a result of firm opposition from local communities and concerns over future water pollution, Newmont was forced to cancel its planned exploration of a nearby mountain (cerro Quilish), which caused the company to re-classify 3.7 million ounces of gold from probable and proven reserves to mineralized non-reserves.[46]

A poor reputation can lead to loss of investment attractiveness and value destruction.[47] A company's reputation can play a key role in gaining access to new reserves in sensitive areas and the ability to obtain permits and approvals on a timely basis. As such, it impacts a company's ability to generate financial returns and growth. In addition, high profile incidents can generate negative media attention and international scrutiny that may turn away potential partners and lenders with impacts on the company's ability to develop new projects and obtain financing. Water management is not the only consideration in how a community perceives a mining operation but it can play an important role. Large international financial institutions are increasingly assessing whether their potential clients have good reputations in the communities where they operate due to the scrutiny the institutions may themselves face from shareholders and activists concerned about the social and environmental impacts of mining.

Reputational risks may extend beyond a single company. A legacy of pollution from mining-related activities can cause local communities to become highly suspicious, if not resistant, to future mines in their local areas. In 2001 the residents of Tambogrande, Peru voted overwhelmingly against a proposed gold, zinc, and copper mine. Cognizant of mining companies' records in Peru, residents worried that a new mine would seriously damage or deplete the water resources needed for agriculture.[48] Similarly, the Summitville Mine in Colorado—an abandoned mine site that resulted in a bill of $150 million in clean up and water treatment costs for U.S. taxpayers—has become the poster child for environmentalists opposing future mine projects.

Section II: Assessing Corporate Water Risks

2.1. WATER RISK ASSESSMENT

Mining companies are not equally exposed to water risks. Risk may be increased as a result of a company's operating practices and the commodities mined, but ultimately a company's exposure to water risks varies according to the geography of its operations, the geological characteristics of the ore bodies being mined, the climate and the type of operations.

WRI presents a preliminary risk assessment framework in Table 2. This risk assessment framework can be used by the financial community to engage companies about geological, climatic, operational, and management considerations to help evaluate potential water risk exposure. Table 2 uses questions developed by Ceres, a U.S. environmental organization, as a basis for organizing the information. This framework provides a starting point for discussion on which feedback is welcomed.

Understanding how a company manages and reports water-related risk can be a useful proxy for evaluating risk exposure —especially when investors and financial intuitions have limited resource for company engagement and sector-specific technical expertise. Specific questions that the financial community can use to assess a company's approach to managing and reporting risk include:

1. **Does the company assess the water usage of its operations?**
    a. Does this assessment identify impacts on other users, including ecosystems?
    b. Does the company identify and assess water resources in their context, including ground and surface water?
    c. Does this assessment account for run-off from rock, waste rock, and other mine workings?
    d. Has the company taken into account permanent diversion of surface or groundwaters and sustained water quality deterioration, such as from acid drainage?
2. **Has the company taken into account potential water-related risks to its operations?**
    a. What percentage of the company's operations is located in water scarce or water stressed areas? Is water demand growing in those areas?
    b. Has the company developed an adequate technological/ managerial response?
    c. How will future regulations and/or price increases affect operations?
    d. What percentage of the company's energy comes from water dependent sources (e.g., hydropower)?
    e. Has the company assessed how climate change may affect water supply for its operations?
3. **Does the company publicly disclose its performance on water-related issues and associated risks?**
    a. Does the company report its water consumption by site by source? Does this data include recycled water?
    b. Does the company report the volume of waste contained in waste rock piles, tailings, and other holding facilities?
    c. Does the company analyze and report the potential for acid drainage at each site? Does it report the amount of potentially acid-generating material is present?
    d. Does the company report how it disposes its waste and the daily/yearly volume of waste disposed into the surrounding environment?
    e. Does the company report the percentage of water in tailings and other wastes?

Table 2: WRI's Water Risk Framework for the Mining Sector

		Surrounding environment	Type of commodity	Type of operation	Corporate Policy/ Approach	Disclosure/ Engagement	Regulatory Climate
Questions for Companies*		*Operating in water scarce regions?* *Competing with other users? Seismic hazard?*	*Grade of ore and ratio of ore to final product?*	*Extraction method, waste disposal, water management procedures?*	*Does the company conduct water footprint analyses?* *How are water risks assessed?*	*Does the company disclose water risks?* *Engage with stakeholders?*	*How will prices, water quality regulations, or other permits affect the company?*
Risk Level	**High**	• Arid/semi arid environments • Presence of other competing uses (agriculture, ranching) • High seismic hazard • Very high rainfall and/or frequent, major storm events • High permeability aquifers	• Low grade ore • Precious metals • Diamonds • Copper • Nickel • Oil shale/ sands	• Open pit that reaches below water table • Dewatering required • High acid drainage potential • Tailings disposed in rivers • Energy derived from hydropower • Large water withdrawals • Large mixing zone for discharges	• No water accounting or footprint analysis • Does not consider water risks	• No reporting against existing frameworks (e.g. GRI) • Does not report tailings effluents • Minimal engagement w/ stakeholders	• Operating in countries with uncertain regulatory climate • Water scarcity a major concern for policy makers • Effluent releases and water withdrawals exceed permits
	Medium	• Moderate seismic hazard • Moderate rainfall with distinct dry season	• Coal • Uranium • Crude oil • Zinc • Lead • Iron ore	• Open pit above water table • Dewatering water recycled • Potentially acid generating material capped and controlled • Tailings stored in impoundment • Energy derived from coal/ natural gas • Moderate water withdrawals • Small mixing zone for discharges (1-2 miles)	• Water balance/ accounting at mine site • Stated policy to reduce water consumption • Developing additional water metrics	• Reports some water indicators (e,g, GRI EN8, EN10, MM3) • Regularly consults with stakeholders at site and global levels	• Company is taking steps to anticipate changes in regulations • Effluent releases and water withdrawals are well within permits
	Low	• Moderate rainfall • Low seismic hazard	• Cement • Other industrial minerals • Natural Gas	• Energy derived from renewable sources • Old mine workings capped and covered • Low acid generating potential • Water flows carefully controlled at site • Water discharges meet ecosystem requirements • All water consumed is reused/ recycled	• Comprehensive direct/indirect footprint analysis • Water risks have been measured and taken into account • Company sets targets to reduce water footprint	• Company discloses data on waste characteristics, flows, water risks • Seeks input and participation of stakeholders	• Company is operating beyond compliance • Zero discharge facility

Source: WRI.

* Questions in this row are from Morrison, J. et al. 2009. *Water Scarcity and Climate Change*, pp. 39-42.

A mining company's operational practices are important for understanding a company's potential exposure to water-related risks. Good operational practices can go a long way to lessening a company's impact on the environment and reducing potential risks. For example, companies may reduce water consumption by implementing water-saving measures, such as reusing and recycling process waters, dewatering tailings, and dewatering pits to avoid a decline in ground and surface waters. Whether or not such measures are enough to avoid physical water risks, including reductions in production or work stoppages, will depend on the severity of the water scarcity problem. In the most water scarce climates, such measures may not be enough to prevent physical water risks from impacting operations. In these cases, desalination technology may be needed to mitigate risk.

Ensuring that mining does not result in contaminated water requires companies to implement sound waste management strategies, prevent and avoid acid drainage, and manage the mine's water balance. The Water Affairs and Forestry Department of South Africa stipulates that the use of water for mining must follow a "mitigation hierarchy" consisting of:

- Preventing or minimizing water pollution;
- Reusing or reclaiming contaminated water;
- Treating water that cannot be reclaimed;
- Reusing treatment water; and
- Safely discharging or disposing of excess water.[49]

Good management is essential to ensuring that these processes are effectively executed.

However there is no single agreed upon set of environmental performance standards for the mining sector. Organizations that have promoted best practice guidelines for the mining industry include:

- The Australia government, NGOs, academics, and industry developed a practical manual on water management titled *Water Management: Leading Practice Sustainable Development Program for the Mining Industry*.[50]
- The International Finance Corporation's (IFC) *Handbook for Pollution Prevention and Abatement* recommends practices on issues related to water use and quality, tailings and waste management, and preventing acid drainage for all IFC sponsored mining activities.[51]
- Australia's Ministerial Council on Mineral and Petroleum Resources (MCMPR) and the Minerals Council of Australia's (MCA) *Strategic Water Management in the Minerals Industry: A Framework* reflects the findings of an industry/government working group with the goal to promote a strategic approach to water management within the mining sector in Australia.[52]
- The International Council for Mining and Metals (ICMM), the industry's largest global association, has a "Good Practice" website that includes water management guidance and best practices from around the world.[53]
- WWF and the Center for Science in Public Participation published a global review of environmental and social practices in the mining sector that includes recommended best practices for water use and quality. This was a largely aspirational document that NGOs used to push for more stringent environmental and social standards in the mining sector.[54]

Appendix IV summarizes the best practices relating to water quality and consumption articulated in the aforementioned publications.

Some leading companies are also taking the initiative to develop their own water accounting methods in order to measure their water "footprint." Measuring a water "footprint" involves calculating the total direct and indirect water use of during operations, and in some cases, the entire product's life cycle. This would include, for example, all of the water required during the stages of the mineral production cycle including exploration, extraction, processing, manufacturing, and transportation (the product's end use and waste/recycling water use may also be considered in some methodologies). A wide array of tools exists for mining companies to use to calculate their water footprint.[55]

Examples of water accounting methods and metrics developed by mining companies include:

- Newmont Mining is using a predictive water balancing tool to develop a site-specific water management plan. The tool provides probabilities of rainfall distribution, a model of the existing water conveyance network, estimates of waste dump seepage and runoff volume, and estimates of runoff quantities from un-impacted watersheds.
- BHP Billiton has developed a water use index that measures the ratio of water recycled and reused to high quality water consumed, where high quality water is defined as having less than 5,000 mg/L of dissolved solids (i.e. drinking water quality standards).
- Rio Tinto has developed a water efficiency metric defined as the ratio of freshwater consumed to tonne of product produced. This metric is used to measure performance against the company's target to reduce freshwater use per tonne of product by 6 percent by 2013 from a 2008 baseline.

2.2. WATER REPORTING: THE STATE OF PLAY

The mining sector achieves a relatively high level of water-related disclosure compared to other industries. This level of water risk disclosure reflects the industry's exposure to physical, reputational, regulatory, and litigation risks—with several high profile incidents in recent years. Two recent studies have ranked sectors with respect to water disclosure and both found that the mining sector scored among the top industries included in the analysis.

- A February, 2010 report by Ceres benchmarked 100 large industrial companies with respect to their corporate disclosure on water-related risks. This study found that the mining sector achieved the highest score for water-related disclosure of all the industries it analyzed.[56] However the report found that the industry's water risk disclosure could be improved as even the highest scoring mining company, Xstrata, scored only 42 of a possible 100 points and the mining sector's average score was 28 out of 100.[57] The analysis found that mining companies' water-related disclosure is strongest with respect to reporting data on water accounting.
- The CEO Water Mandate[58] commissioned the Pacific Institute to assess corporate reporting on water-related information. The March 2009 report finds that the industrial metals and mining sector ranks second with respect to reporting (after food and beverage). Yet there is room for improvement as companies in the sector report an average of only 8 out of 20 possible criteria. As with the Ceres study, reporting is best with respect to water usage with 80 percent of companies assessed including information about water use in direct operations.[59]

Within the sector, mining companies vary with respect to the quality of their water-related disclosure. WRI surveyed the corporate disclosures (annual filings, sustainability reports, and websites) from 43 major mining companies with market capitalizations above $5 billion that operate in diverse regions across the globe. The findings show that a majority of the mining companies report some water consumption information, with the largest international companies also reporting additional water management strategies and/or indicators.

However, water disclosure from major companies in emerging economies varies widely, with South African and Latin American companies generally reporting the most water-related data. Most Chinese and Indian mining companies report little or no water-related information. This trend is alarming as companies from these countries are growing in prominence and many regions within China and India are expected to experience increased water scarcity in coming years.[60] [61] See Appendix V for the survey results.

Current reporting frameworks do not guide companies to report the full scope of potential water risks. While there is no agreed upon environmental disclosure methodology for any sector, most mining companies use the indicators developed by the Global Reporting Initiative (GRI). The GRI is a network-based organization that has developed a voluntary sustainability reporting framework, with the mining sector having the third highest number of participating companies of any industry.[62] However as noted in the rest of this section, there are limits to the extent to which current GRI indicators provide all the information required by the financial community to evaluate risk. See Table 3 for the water-related indicators included in the mining and metals sector supplement of the GRI.

Table 3: Water-related GRI Indicators (from Mining and Metals Sector Supplement)

GRI Indicator		Requirement*
EN 8	Total water withdrawal by source	Mandatory
EN 9	Water sources significantly affected by withdrawal of water	Voluntary
EN 10	Percentage and total volume of water recycled and reused	Voluntary
EN 21	Total water discharge by quality and destination	Mandatory
EN 25	Water sources and related habitats significantly affected by discharge of water	Voluntary

* GRI is a voluntary reporting framework. This column indicates requirements for those organizations electing to use the GRI principles for reporting sustainability information. http://www.globalreporting.org

Gaps in Current Disclosure Practices

A clearer understanding of the mining industry's exposure to water risks would require:

a) More detailed **water metrics**, especially relating to water quality concerns;

b) **Contextual information** to understand water risks as they relate to a particular operating environment; and

c) Improved **consistency** in calculating and reporting water metrics across companies in the sector.

a. Water Metrics

Most water usage data is reported at the aggregate corporate level, which is insufficient for risk assessment purposes. Water withdrawals, use or consumption are the most widely reported water-related metrics, corresponding to GRI indicator EN 8 (total water withdrawal by source). In many cases this data is only reported at the corporate level, which does not provide an adequate level of detail as physical water risk is very specific to the conditions of a particular mine site. In the best cases, water data is disclosed by mine site, water source, and operational activity. However this level of disclosure is not specified in the GRI guidelines and is left to the discretion of the company.

Water quality problems associated with mining are often not accounted for. In the case of the GRI, disclosure of water discharges (EN 21) is reported against local water quality standards. However, this metric does not provide information on potential water contamination risks due to acid drainage and other waste management problems, which often are the most serious liabilities facing mining companies. More detailed information is needed about potentially acid-generating material by location, the chemical composition of waste rock, tailings, and other wastes, and measurements/indicators of effective stormwater runoff management. Ideally companies would report the results of acid drainage studies to alert investors and lenders to potential problems.

In most cases, water "footprint" methods developed by mining companies only focus on water consumption and do not account for water quality impacts. As a result, water management strategies focused on reducing water consumption do not provide insight into how a company is positioned with respect to potential risks from contaminating local water supplies. For example:

- Stormwater or runoff from waste rock, stockpiles, or other mine workings are not reported.
- Companies do not report the character of the effluents stored and released, making it difficult to ascertain the toxicity of mine effluents.
- The chemical composition of waste rock or other potentially acid generating material is typically not reported.

The impact of mining activities on other water users is also rarely reported. Using the GRI, companies may elect to report on EN25 (water sources and related habitats significantly affected by discharge of water).

However in most cases these disclosures discuss past spill incidents and do not provide insight into the potential for future impacts. In addition, this interpretation of EN 25 does not capture the effects of mining water withdrawals on the availability of water within the whole watershed. During open pit mining, companies often must de-water the pit to allow safe access to progressively deeper parts of the ore body. This water may be re-used and recycled in the processing stage. However, such withdrawals often affect groundwater resources, and hence water availability for neighboring users.

b. Context for Interpreting Water Risks

Water consumption and footprint metrics require context to interpret potential risk. All water is local, thus water consumption data is only relevant when placed in the context of local water availability. In water scarce regions, risks from physical water constraints are often higher than they might be in water abundant regions. However, no metrics comparing water usage to water scarcity are currently used by companies publicly reporting through the GRI or company-specific frameworks. The water use data that is readily reported by the industry is therefore difficult to interpret as factors such as water availability, demands from competing uses, demographic pressures, and issues affecting water quality must be considered to fully understand water risk.

Water availability may also affect the reliability of thermal and hydro power sources with impacts on the industry due to mining's high energy requirements. Yet most companies do not report the source of energy used in their operations, making it difficult to estimate the magnitude of water-related energy risks in their operations. GRI indicators require companies to report energy consumption by source, but not by primary origin. It is therefore difficult to ascertain which companies may be vulnerable to water risks as a result of reliance on hydropower or thermal power. Two companies, Rio Tinto and BHP Billiton, provide exceptions by reporting their utilization of hydropower for direct energy consumption at their facilities. In addition, Rio Tinto reported that in 2008, 22 percent of its energy requirements were met by hydropower, which also accounted for 57 percent of its electricity needs.[63]

c. Reporting Consistency

How companies interpret and report against water-related indicators varies widely. As a result, the financial community cannot easily compare companies within the sector to understand relative risk and performance. The utility of the reported data is therefore diminished. While the GRI is the most comprehensive framework currently available, it is difficult to compare company water performance using GRI indicators for the following reasons:

- EN 8 (total water withdrawal by source) does not detail how to calculate and report water withdrawals, so companies use different methodologies in their reporting. As a result it is difficult to understand if factors such as water reuse and recycling are considered.
- Little to no explanation is given to major changes in the values reported under EN 8 (total water withdrawal by source). In some cases, facilities report major shifts in water withdrawals from one year to the next, but there is no scope for explanations as to the reason for vastly different values.
- EN 9 (water sources affected by water withdrawals) is rarely reported against, except as a textual notation.
- Many companies do not report against EN 10 (volume of water recycled), which raises questions about the values reported against EN8 (total water withdrawal by source), as most mining companies recycle and reuse water withdrawn for processing.[64]
- EN 21 (total water discharge by quality and destination) requires companies to report the quality of water discharges according to local permits and regulations. Local regulations vary greatly, and in some cases (e.g., mines that release tailings into rivers in Papua New Guinea), companies have negotiated separate agreements with governments to allow extra-legal water discharges. Therefore it is important to know if the values reported under this indicator are reflective of the mine's special

arrangement or the normal water quality standards in that jurisdiction.

- With EN 21 (total water discharge by quality and destination) it is not clear whether the volumes reported occur at the point of discharge or at the end of a (sometimes lengthy) mixing zone.
- EN 25 (water sources and related habitats significantly affected by discharge of water) is rarely reported and impacts on water availability in the watershed are not considered.
- There is no standard definition of "hazard" when reporting mining waste**.** The GRI's mining and metals working group has recommended adding an indicator (MM3) to the next version of the sector supplement which requires companies to report the total amount of waste rock, overburden, rock, tailings and sludges that pose an environmental "hazard". However, the definition of hazard is left to the discretion of the company.

Reporting about water management systems may not be supplemented with data on actual water performance at the mine site. Water footprints can be a powerful tool to monitor and manage water performance and targets. Leading companies are developing comprehensive water management systems that are often described in detail in corporate disclosures. However, many companies do not report the resulting data on water performance to the public in enough detail to be useful. As a result it is difficult to understand the effectiveness of such management programs.

In addition, water footprinting metrics developed by companies use different methodologies and metrics to calculate and monitor water usage. As a result it is difficult or impossible to compare management systems and water performance across companies in the sector. Addressing this issue would require a standardized approach to water accounting that includes detailed guidance on water data reporting.

Improving Disclosure

Table 4 includes suggestions for more detailed and comprehensive metrics that could be used as a starting point for ascertaining a mining company's water-related risks. A more complete and definitive list of metrics would be a valuable contribution to future disclosure frameworks.

Table 4: Additional Metrics for Determining Water-Related Risks to Mining Companies

Issue	Metric
Water Availability	• Water content of tailings and retention ponds • Withdrawals in water scarce basins • Number of operations in water scarce basins • Withdrawals compared to available water and other competing uses in the watershed • Total water consumption by site, source (e.g. groundwater), use (e.g., dewatering pits, processing, dust suppression, mine camps) • Recycled/reused water by use (as above)
Water Quality	• Water quality consumed versus discharged • Discharges by water quality (e.g. to sea water, groundwater, freshwater) • Total potentially acid-generating material by location (e.g. pit walls, waste rock piles, tailings) • Chemical composition of waste rock, tailings, and other wastes • Run-off, stormwater and other water releases by volume, chemical composition, and destination • Water releases compared to baseline water quality of surrounding water resources (groundwater and surface waters)

Source: WRI.

2.3. LOOKING AHEAD: TOWARD A BETTER UNDERSTANDING OF WATER RISK

As this report illustrates, water plays a major role in the mining sector and its availability and quality can create a number of challenges for the industry. Companies face water supply risks in arid and semi-arid regions, and water pollution from mining can result in fines, loss of reputation, and costly litigation in any operating environment. While most major mining companies have started to address water-related risks, current reporting frameworks do not guide companies to disclose the full scope of potential water risks to the financial community. In particular, disclosure largely focuses on water usage data, rather than extending to the broader water-related risks faced by companies due to their impact on the quality and quantity of local water supplies.

Water risks are likely to increase over time as mineral demand grows, ore grades decline, climate change intensifies, and economic and demographic trends strengthen competition for water resources. Mining sector stakeholders have important roles to play to improve the quality of water disclosures to better reflect water-related risks facing companies today and in the future. Specifically:

- ***Mining companies and industry groups*** can work together to develop a common accounting methodology in order to create better water metrics.
- ***Multi-stakeholder engagement group, including investors, financial institutions, companies, and NGO's*** can provide further guidance on disclosing water information in order to improve and standardize company reporting.
- ***NGO's, in partnership with companies and the financial community,*** can lead the development of indicators or metrics to contextualize water consumption data.

Indeed, important efforts for these stakeholder groups to improve water disclosure are currently under various states of development. The following reviews three initiatives of particular importance:

MCA's Water Accounting Framework (for better water metrics)

The financial community can better evaluate a company's exposure and performance on water-related issues with better and more consistent data. Water metrics must be calculated using the same methodology in order to be comparable across companies within the industry and with other important water users.

Since 2005, members of the Minerals Council of Australia (MCA) have been developing a water accounting framework to provide guidance and consistency on identifying, measuring, monitoring and recording water balance information across companies in the mining sector in Australia. The efforts are now being piloted internationally through the International Council on Mining and Metals (ICMM). The current version of the framework provides:

- A consistent approach for quantifying flows into, and out of, reporting entities, based on their sources and destinations.
- A consistent approach for reporting 'water use' by minerals operations that enables comparison with other users, and relates to water sharing planning processes.
- A consistent approach to quantifying and reporting water 'reuse' and 'recycling' efficiencies such that the reliance on sourced water is reduced.
- A model for the more detailed operational water balance as guidance for those businesses which currently do not have an effective operational water model or see an opportunity to develop this new approach.

More information is available at:
http://www.wateraccounting.net.au/wiki/SMI_MCA

IIRC's Integrated Reporting Initiative (to improve consistency of disclosure)

While accounting standards can help improve the quality of data, guidance is necessary to encourage consistent reporting of this data and information. Furthermore, there is important information that is not covered in accounting frameworks, including management strategies, risks beyond the boundaries of the mine, and indicators of potential water quality problems. A consistent approach to reporting water information is needed to raise the level of disclosure for all companies in the mining sector.

A coalition of businesses, financial institutions, regulators, accountants, securities exchanges and not-for-profit groups recently launched an International Integrated Reporting Committee (IIRC) initiative to "create a globally accepted framework for accounting for sustainability." Jointly convened by HRH Prince Charles's UK-based Accounting for Sustainability Project and the Global Reporting Initiative, the committee includes participants from the International Accounting Standards Board, U.S. Financial Accounting Standards Board, International Organisation of Securities Commissions, asset managers including APG Group, the Big Four auditors —Price Waterhouse Coopers, Deloitte, Ernst & Young and KPMG —and NGOs including the World Resources Institute. The committee intends to present a framework that brings together financial, environmental, social and governance information in a single "integrated" reporting format at the G20 intergovernmental summit in France in 2011. If successful, such a format will encourage much greater consistency in reporting water-related data and information across the mining industry. More information is available at: http://www.integratedreporting.org/

WRI's Water Risk Index (to contextualize risk)

The financial community needs information about the local context of a mining company's water use before it can interpret the underlying financial risk stemming from water availability and quality concerns—especially in light of trends such as increasing water scarcity, intensifying competition for water resources, and more stringent water regulations that are affecting many regions of the world. Localized water footprint and water risk calculations are complementary as they help the financial community to understand mining companies' exposure and response to ambient water risks. A combined metric ("risk-adjusted footprint") could be the basis for assessing an operation's exposure to water risks and possibly a ranking of companies by their (aggregated) water risk.

To fulfill this need the World Resources Institute—with support from Goldman Sachs and General Electric—has developed a prototype Water Risk Index to measure and map these geographic water-related risks. The tool is watershed-specific and builds on the WBCSD's Global Water Tool[65] by providing higher resolution, more coverage (beyond physical water scarcity to include economic, social, and governance issues), and a predictive capacity (as it analyzes time series of publicly available data and indicators). In addition, the Water Risk Index is developing a standard reporting framework that aggregates contextualized water use information at the company level so that corporate water performance can be meaningfully compared across companies. This will enable the financial community to better evaluate water-related risks facing companies in the mining sector.

A prototype of the Water Risk Index has recently been completed for the power generation sector in the Yellow River Basin of China. The project aims to expand globally and encompass all industrial sectors in the next phase. For further information on this effort, please contact Piet Klop at pklop@wri.org.

Each of these initiatives is a challenging undertaking that requires extensive buy-in from diverse stakeholder communities. There is no magic bullet solution: rather each aims to develop a workable approach that can be refined over time as environmental, social, technological, and economic issues evolve. Furthermore, stakeholders must ensure that these efforts do not leave out important aspects of water risk disclosure, including how to better characterize and report potential risks relating to water quality concerns – especially acid drainage.

The financial community has an important role to play to encourage improved water disclosure in the mining sector. By participating in these efforts and engaging with companies directly, investors and financial institutions create a strong incentive for the industry to better disclose data and information on water availability and quality issues. Improved disclosure will help the financial community navigate complex water risks that are becoming increasingly important as industry and environmental trends converge and water becomes a considerable factor affecting growth and profitability in many regions of the world.

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ABOUT WRI

The World Resources Institute (WRI) is an environmental think tank that goes beyond research to find practical ways to protect the earth and improve people's lives. Our mission is to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations.

Because people are inspired by ideas, empowered by knowledge, and moved to change by greater understanding, WRI provides—and helps other institutions provide—objective information and practical proposals for policy and institutional change that will foster environmentally sound, socially equitable development.

WRI organizes its work around four key goals:

- *Markets & Enterprise*: Harness markets and enterprise to expand economic opportunity and protect the environment.
- *People & Ecosystems*: Reverse rapid degradation of ecosystems and assure their capacity to provide humans with needed goods and services.
- *Governance*: Empower people and strengthen institutions to foster environmentally sound and socially equitable decision-making.

- *Climate Protection*: Protect the global climate system from further harm due to emissions of greenhouse gases and help humanity and the natural world adapt to unavoidable climate change.

In all its policy research and work with institutions, WRI tries to build bridges between ideas and action, meshing the insights of scientific research, economic and institutional analyses, and practical experience with the need for open and participatory decision making.

APPENDIX I: OVERVIEW OF THE MINERAL DEVELOPMENT CYCLE

As can be seen from Table A, mineral commodities have multiple uses. Most mineral commodities undergo several processes before being manufactured into finished products.

Table A: Select Mineral Commodities by End Use

Commodity	End Uses
Aluminum	Aircraft, automotive parts, railroad cars, ships, packaging, building construction, electrical applications, pharmaceuticals, water treatment
Cadmium	Electroplating, nuclear reactor parts, televisions, batteries
Cement	Building construction, concrete, roads, bridges, sewer and water systems
Cobalt	Super alloys for jet engines and turbines, magnets, stainless steel, electroplating, batteries, diamond tools, pigments
Copper	Building construction, aircraft and automotive parts, machinery, furniture, coins, jewelry, artwork, musical instruments, cookware
Diamonds	Jewelry, diamond tools
Gold	Jewelry, electronics, dentistry, bathroom fittings, decorative fine arts, store of value
Iron ore	Steel-making, alloys
Lead	Batteries, cable sheathing, lead crystal, solder, plumbing, ammunition
Manganese	Steel-making, alloys, batteries, water treatment, fuel additives, catalysts, sealants, circuit boards
Nickel	Stainless steel, alloys, gas turbines, plating, coins, batteries
Platinum group metals	Catalytic converters, jewelry, glass, electronics, implants and medical devices, anti-cancer drugs
Silver	Photography, jewelry, electrical applications, batteries, solder and brazing alloys, tableware, mirrors and glass
Tin	Tinplates, alloys, solder, pewter, chemicals, panel lighting
Zinc	Galvanizing, alloys, brass, batteries, roofing, water purification, zinc oxide (used in paints, cosmetics, and pharmaceuticals), TV screens, X-ray, fluorescent lights

Source: MMSD, 2002.

The basic stages of the mineral development cycle are summarized below.

Exploration

Mining begins with exploration of a potential ore body to determine its size, extent, quality, and economic feasibility of development. Initial exploration consists of aerial surveys, supplemented by remote sensing and mapping. If geologists find that the ore body holds promise, field exploration follows. This usually entails drilling core samples from various points at and near the deposit to ascertain its size and economic value. Should the results from exploration prove fruitful the company will obtain the necessary environmental and occupation permits to begin mine site construction and development.

Extraction

Most minerals are extracted either via underground or surface mining. Designed for vertical veins that penetrate far beneath the earth's surface, underground mining entails construction of deep shafts through which ore is transported to the surface via rail, conveyor belts, or elevators. Relatively shallow and/or expansive deposits are exploited via surface mining, which uses excavators to remove waste rock and overburden located above the deposit. A type of surface mining, open-pit mining, involves the creation of concentric rings and platforms from which ore is extracted, eventually creating a pit up to several kilometers wide by a kilometer deep. The most common extraction method, open-pit mining is typically used for deposits that reach the surface but whose irregular shape and depth require deeper extraction methods.

Processing

Once the valuable ore has been extracted it is usually processed in one or more stages. Initial processing almost always occurs on or near the excavation site. For non-fuel mineral commodities, processing begins with the grinding and crushing of the ore to separate the non-valuable materials from the target mineral(s) using flotation, gravity separation, or heap leaching methods:

- *Flotation:* chemicals or reagents are combined with the valuable mineral particles in a concentration circuit to separate the target minerals from the uneconomical ore. Chemicals and reagents used in this process may include cyanide, sodium sulfide, ammonia, lime, and fuel oil.

- *Gravity separation:* minerals are differentiated on the basis of their weight and density; fewer chemical reagents are used than in flotation or heap leaching.
- *Heap leaching*: Ore containing the target mineral is heaped on leaching pads and a chemical or reagent solution--typically cyanide or sulfuric acid--is sprayed over the ore, causing the target mineral to precipitate and filter to collection ponds. This technique is used primarily for low grade gold and copper ores.

The product of the primary processing phase of metals is a liquid concentrate, which is transported to a smelter for further processing and refining. Smelting involves heating the concentrate to melt the metal and remove impurities. The purified molten metal is poured into molds to form ingots or slabs, which are then shipped to manufacturing centers. Metals requiring further purification, such as zinc, copper and lead, are sent to a refiner where "electrorefining" occurs.

Manufacturing and Fabrication

Purified minerals and metals are sold to manufacturing facilities to be cut or cast into specific, pre-determined forms for use in other industries, or for fabrication in consumer products. This may include rolling, extruding, or machining to form semi-finished products that can be used in equipment manufacture. At this stage, the number of processing stages required depends on the mineral or metal and the end-use application. In general, the fabrication process occurs far from the mine site, except for some large volume, low value minerals, such as cement and salt, which are not typically transported over long distances.

Recycling, reuse, and re-manufacturing

Minerals that retain their chemical form may be suitable for recycling and reuse. Three types of metal scrap are recycled:

- "Home" scrap—generated at the metal refining stage and usually fed back into the melting furnace.
- New scrap—generated during the manufacturing process, collected and processed in secondary refineries for reuse.
- Old (post-consumer) scrap—generated from discarded consumer products, collected, and sent to secondary refineries for processing and reuse.

The rate at which metals are recycled at the post-consumption stage varies greatly, depending upon regulatory requirements, availability, and ease and cost of collection.

APPENDIX II: OVERVIEW OF KEY ENVIRONMENTAL ISSUES IN THE MINING INDUSTRY

The minerals development cycle include complex and intensive processes with the potential for serious environmental consequences, including ecosystem disruption, water contamination, and greenhouse gas (GHG) emissions. When managed well, the negative environmental and social impacts of mining can be limited, but the negative consequences of mines using destructive practices can be much broader and last for decades and even centuries.

Table B provides an overview of environmental impacts at different stages in the mining process. The most serious issues tend to occur in the extraction and processing phases from the production, storage and disposal of vast quantities of waste, often including toxic materials that can leach into soils and contaminate water supplies.

Table B: Potential Environmental Impacts by Stage of Mining

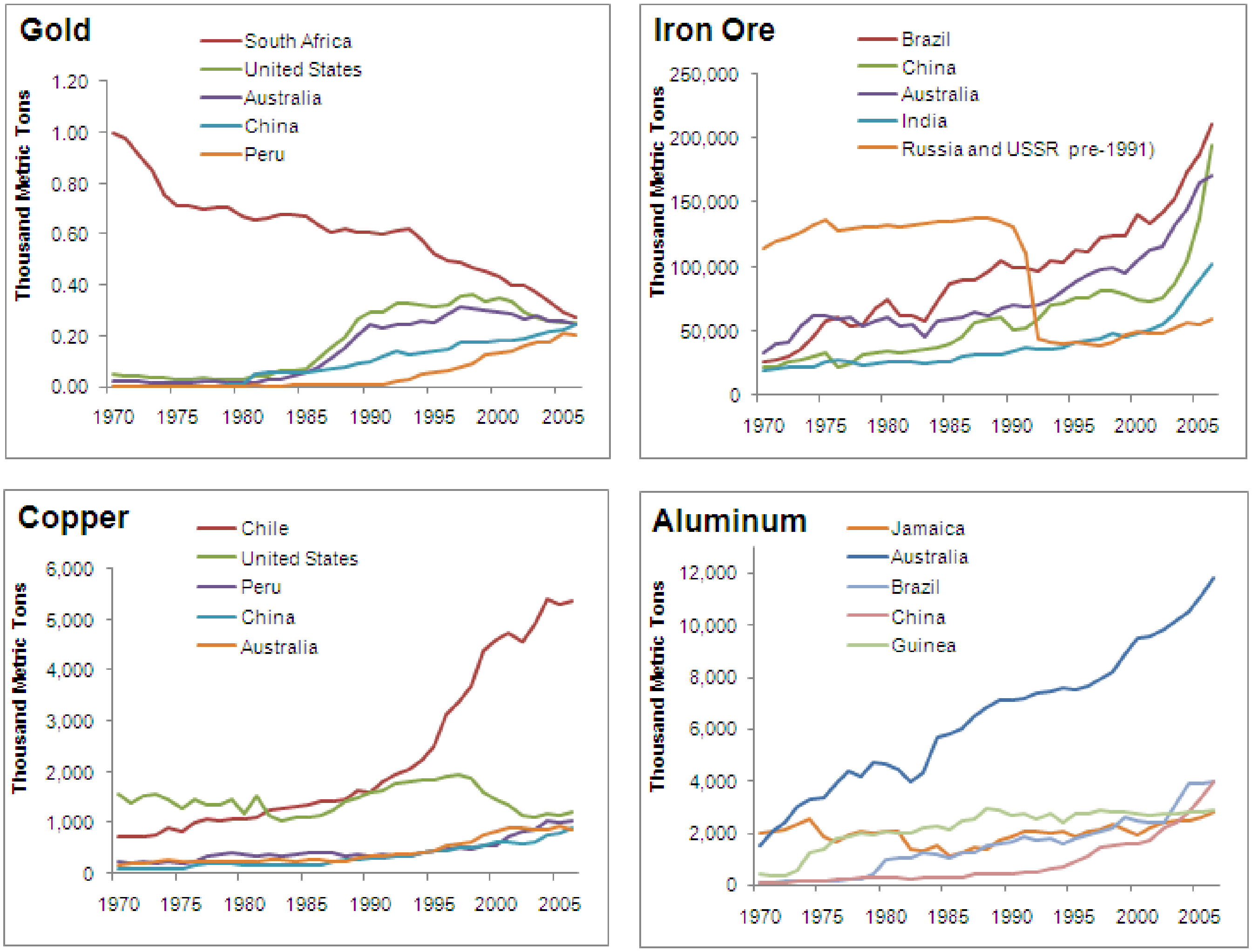
Stage	Activities	Potential Environmental Impact
Exploration	• Geophysical/airborne surveying • Drilling/trenching • Trench blasting • Exploration camp development • Road construction	• Habitat loss/fragmentation • Sediment runoff, increased suspended sediment load to surface waters • Disturbance to wildlife • Spills of fuels and other contaminants • Greenhouse gas emissions related to blasting, infrastructure development
Site preparation/ mineral excavation	• Mine construction • Infrastructure development (power lines, roads) • Mine camp construction • Creation of waste rock piles • Creation of low- and high-grade ore stockpiles • Creation of waste impoundments • Blasting to release ores	• Habitat loss/fragmentation • Chemical contamination of surface and ground waters • Declining species populations • Toxicity impacts to organisms (terrestrial and aquatic plants and animals) • Altered landscapes from mine workings (e.g., open pits, changes in stream morphology) • Increased demand for water resources • Increased demand for electrical power • Increased erosion and siltation • Altered patterns of drainage and runoff • Greenhouse gas emissions related to explosives
Primary processing	• Milling/grinding ore • Ore concentration through chemical leaching, flotation, electrowinning, or gravity separation	• Discharge of chemicals and other wastes to surface waters • Missions of sulfur dioxide, nitrous oxides, and heavy metals (lead, arsenic, cadmium) • Increased demand for electrical power • Greenhouse gas emissions related to energy consumption from milling and separating ore.
Secondary/ tertiary processing	• Smelting/refining	• Emissions of sulfur dioxide, nitrous oxides, and heavy metals (lead, arsenic, cadmium) • Increased demand for electrical power • Discharge of chemicals and other wastes to surface waters • Off-gasing and toxic dusts • Greenhouse gas emissions related to smelting
Product transport	• Packaging/loading product • Transport via sea or land • Infrastructure development	• Noise disturbance • Greenhouse gas emissions related to fuel use • Water added to ore concentrates to facilitate transport
Mine-closure/ post-operation	• Reseeding/revegetation • Re-contouring waste piles/pit walls • Fencing dangerous areas • Monitoring seepage	• Persistent contaminants in surface and groundwaters • Expensive, long-term water treatment • Persistent toxicity to organisms • Loss of original vegetation/biodiversity • Windborne dust • Permanent landscape changes • Abandoned pits/shafts that pose hazards and health risks

Source: Adapted from Marta Miranda et al. 2003. *Mining and Critical Ecosystems: Mapping the Risks*. WRI: Washington, DC.

APPENDIX III: TOP MINERAL PRODUCING COUNTRIES

North America, Australia, Chile, and South Africa have traditionally dominated global mineral production. Australia remains a mining powerhouse, supplying much of the world's demand for aluminum, iron ore, lead, manganese, and titanium dioxide. However in recent years, production of major mineral commodities has been shifting toward other countries, especially in Asia. See Figure A.

Figure A: Top Gold, Iron Ore, Copper, and Aluminum Producing Countries: 1970-2006



Source: USGS, Minerals Yearbook, 2006

APPENDIX IV: SUMMARY OF BEST WATER-RELATED OPERATIONAL PRACTICES

The information below summarizes the best operational practices relating to water quality and consumption articulated in the following documents:

- Australian Department of Resources, Energy, and Tourism, 2008. *Water Management: Leading Practice Sustainable Development Program for the Mining Industry.* Canberra.
- IFC. 2007. *Environment, Health, and Safety Guidelines: Mining*. IFC: Washington, DC.
- MCMPR and MCA, 2006. *Strategic Water Management in the Minerals Industry: A Framework.* Canberra.
- International Council on Mining and Metals, 2006, *Good Practice Guidance for Mining and Biodiversity*. London.
- Miranda, M., Chambers, D., Coumans, C. 2005. *Framework for Responsible Mining: A Guide to Evolving Practices*. WWF/CSPP: Washington, DC.

It is imperative to note that there is no consensus on these practices and in some cases suggested practices from one source may conflict with those from another or may even be considered controversial.

Suggested Practices for Tailings Impoundments

- Disposal of tailings in riverine or shallow marine environments is not considered international best practice.
- Siting of impoundments should take into consideration topography, downstream receptors, and physical composition of the tailings.
- Impoundments should be lined with synthetic or natural liners, preferably including several backup liners should the primary liner fail to contain wastes.
- Impoundments should include a leak detection system to ensure that toxic wastes do not seep through to ground and surface waters.
- Structures should be constructed according to international dam standards, such as the International Council on Large Dams (ICOLD).
- Construction should take into account any major seismic and/or flood events, and the impoundment should be designed to withstand the maximum event.
- Dewatering tailings should be considered to minimize the mobility of tailings; water captured from tailings should be reused in mine processing.

Suggested Practices for Heap Leach Pads and Waste

- Heap leach pads should be constructed with synthetic liners and leak detection monitoring systems.
- Water used in heap leaching should be captured and reused.
- Leachate collection and water treatment should continue until water quality is not toxic to aquatic organisms.

Suggested Practices for Cyanide

- Compliance with the Cyanide Management Code for gold mining, a voluntary effort aimed at ensuring that companies apply the best technologies and precautions when transporting, using, and disposing of cyanide.
- As the Code does not guarantee that a cyanide leak will not occur, companies should also report on cyanide compounds not covered by the code (specifically cyanates and thiocyanates) which can pose a high risk to aquatic organisms.

Suggested Practices for Waste Rock Dumps and Ore Stockpiles

- Potential acid generating material should be isolated and monitored to ensure that acid drainage does not occur.

Suggested Practices for Mine Water Balance

- A mine water balance should be developed to ensure that water withdrawals and discharges do not negatively impact the watershed and aquatic ecosystem.
- Water discharged should be treated to meet requirements that do not significantly impact aquatic species and habitat.

- The use of mixing zones should be minimized and the area of the zone should be restricted so as to avoid significant impact to aquatic species and habitat.
- Storm water and run-off should be carefully managed to avoid excessive erosion and siltation of nearby water bodies.
- Roads, embankments, rock piles, and any pits should be constructed to avoid excessive run-off and siltation (e.g., using contouring, terracing, slope reduction, etc.)

Suggested Practices for Management

- Water management should be integrated across departments with a coordinating body with authority and responsibility for developing the operation's water management plans, tools, and processes.
- A comprehensive water management plan should identify impacts on other users, upstream and downstream of the operation, including impact on ecosystems
- A zero discharge facility should be a stated goal of the mine.
- A spill and emergency response plan that anticipates worst case scenarios and provides adequate response to contain and minimize spills should be in place.
- Every effort should be made to avoid perpetual water treatment or groundwater pumping beyond the mine site.

APPENDIX V: WATER-RELATED DISCLOSURE BY MAJOR MINING COMPANIES

WRI surveyed the corporate disclosures (annual filings, sustainability reports, and websites) from a sample of major mining companies located operating in diverse regions across the globe. The selected companies presented in Table C are primarily focused on metals and minerals mining activities and have a market capitalization value of at least US$5 billion. The table is organized by market capitalization as of July 27, 2010.

Table C: Water Disclosures Reported by Company

Company (Location of Headquarters)	Market Cap. (Billion USD)*	Location of Mining Operations	Metals/Mineral Commodities Mined	GRI Water Indicators reported**	Additional Water-related Info Disclosed
BHP Billiton (Australia)	$376.95	25 countries including: Australia, Chile, Brazil, Columbia, South Africa, US, Canada	Alumina, coal, copper, lead, zinc, manganese, iron ore, uranium, nickel, silver, titanium, diamonds	EN8, EN9 (partial), EN10, EN21	• Target of 10% reduction in freshwater use by 2012 • Water Use Index (water recycled to high quality water consumed) • All sites with fresh water consumption greater than 500 ML per year have and maintain water management plans
Rio Tinto (United Kingdom and Australia)	$237.24	Primarily in Australia, Canada, US, Europe	Alumina, copper, diamonds, energy products, gold, industrial minerals, iron ore	EN8; EN21	• Total freshwater withdrawals by year • Target 6% reduction in freshwater use per tonne of product by 2013 (2008 baseline) • Water efficiency metric • Water risk framework
Vale (Brazil)	$142.52	35 countries, including: Brazil, Chile, Argentina, Canada, Australia, China, India, Indonesia, South Africa, Angola	Iron ore, nickel, alumina, copper, manganese, coal	EN8; EN10	• Total water withdrawals by type and year • Total volume of liquid effluents generated by type and destination • Planning to develop consistent metrics and water use targets • Regional water availability studies conducted for some sites
Sterlite (India)	$142.50	India, Australia	Alumina, copper, zinc	EN8, EN9, EN10, EN21	• EN9, EN10, EN21 focused on processing plants
Implats (Zimbabwe)	$123.79	South Africa, Zimbabwe	Platinum	EN8, EN10	• Info on water source by mine • Water consumption/withdrawal/ recycled data by mine by year
Kumba Iron Ore (South Africa)	$117.16	South Africa	Iron ore	EN8, EN9	• Corporate water consumption data by year • Yearly water consumption targets
Gold Fields (South Africa)	$67.96	South Africa, Ghana, Australia, Peru	Gold	EN8, EN9, EN21, EN25	• Water withdrawal data by year by mine • Information on water licenses
Anglo American (United Kingdom)	$51.74	South Africa, Australia, Chile, Brazil, Columbia, Venezuela, USA, Canada	Platinum, diamonds, copper, nickel, iron ore, coal	None	• Developing corporate water footprint metrics
Zhongjin Gold (China)	$45.48	China	Gold, copper, lead, silver	None	• None
Barrick (Canada)	$40.75	US, Canada, Chile, Peru, Australia, Papua New Guinea,	Gold, copper, silver	EN8, EN9, EN10, EN21	• Total water use by purpose • Total water discharged • Volume/contaminant for spill incidents

		Tanzania			
Norilsk (Russia)	$31.95	Russia	Nickel, palladium	EN9	• Discusses GRI indicators in terms of relative reductions year over year.
Xstrata (Switzerland)	$30.70	19 countries, including: Canada, Chile, Peru, Zimbabwe, Indonesia, Australia	Copper, ferrochrome, nickel, vanadium, zinc, platinum, gold, cobalt, lead, silver	EN8, EN9, EN10, EN21, EN25	• Water use data reported by water scarce site • Target to achieve 5% reduction of fresh water intensity on 2007 performance by 2010 in water-scarce regions
Newmont Mining (United States)	$30.50	US, Australia, Peru, Indonesia, Ghana, Canada, New Zealand, Mexico	Gold, copper	EN8; EN9 (partial); EN10; EN21	• Total water withdrawals • Predictive water balancing tool
Freeport McMoran (United States)	$29.93	US, Chile, Indonesia	Copper, gold	EN8 (except Arizona and Colorado); EN9 (partial); EN10; EN21	• None
Goldcorp (Canada)	$29.59	Canada, US, Mexico, Honduras, Guatemala, Chile, Argentina	Gold	EN8, EN9, EN10, EN21, EN25	• Water consumption by year • Water discharged by year and source
Southern Copper (United States)	$26.75	Peru, Mexico	Copper, zinc, lead, silver	EN8, EN10	• Water consumption by unit • Water consumption and efficiency indicators
Anglo Platinum (South Africa)	$25.75	South Africa, Zimbabwe, Brazil	Platinum	EN8, EN9, EN10, EN21	• Data on water use by water quality and activity type • Source of water supplies • Water footprint model in use at site level • Will set water reductions targets for next year
Western Mining (China)	$25.21	China	Copper, lead, zinc, iron, manganese, gold, silver, and alumina	None	• None
KGHM (Poland)	$21.00	Poland	Copper	None	• None
Teck (Canada)	$20.70	Canada, US, Chile, Peru	Copper, zinc	EN8, EN10	• None
Chalco (China)	$17.84	China	Alumina	None	• None
Newcrest (Australia)	$15.85	Australia, Indonesia	Gold, copper	EN8, EN9, EN10, EN21, EN25	• Detailed water use data at mine site • Detailed water effluent and waste management data • Data reported based on pilot test of MCA Water Accounting Framework
Basic Element (Russia)	$15.65	Russia	Alumina	None	• None
AngloGold Ashanti (South Africa)	$14.32	South Africa, Ghana, Mali, Australia, Brazil, Tanzania, US, Guinea, Argentina, Namibia	Gold	EN8, EN21	• Water usage and efficiency broken down by site by year • Cyanide usage by site
Fortescue (Australia)	$13.42	Australia	Iron ore	EN8	• Total groundwater use by activity

Evraz (Luxembourg)	$13.33	Russia, Ukraine	Iron ore, coal	None	• None
Zijin Mining Group (China)	$11.47	China	Gold, silver, copper, zinc	None	• Data on discharges from the Zijinshan Gold-Copper Mine
Kinross (Canada)	$11.46	US, Chile, Brazil, Ecuador, Russia	Gold, silver, copper	EN8, EN9, EN10, EN21, EN25	• Water use data by mine by activity by year • Water withdrawals and discharges by mine by year
Jiangxi Copper (China)	$9.94	China	Copper, sulfur, gold, silver	None	• None
Buenaventura (Peru)	$9.86	Peru	Gold, silver, zinc	None	• None
Antofagasta (Chile)	$9.80	Chile	Copper	EN8, EN9, EN10, EN21, EN25	• Water consumption by site, type, and year • Water discharges by type and year • Spill incident data • Water withdrawals by site, source and year • Effluent discharge quantities by amount and final destination
Lihir (Papua New Guinea)	$9.62	Papua New Guinea, Australia, Côte d'Ivoire	Gold	EN8, EN9, EN10, EN21, EN25	• Discussion of deep sea tailings
Agnico-Eagle (Canada)	$9.54	Canada, Finland, Mexico, US	Gold	EN8, EN9, EN10	• Water use and discharge data by source and site
Polyus (Russia)	$8.79	Russia	Gold	EN8, EN9, EN10, EN21	• None
Shandong Gold (China)	$7.44	China	Gold, silver	None	• None
Fresnillo (Mexico)	$7.42	Mexico	Silver, gold	None	• None
Yamana (Canada)	$7.06	Brazil, Argentina, Chile, Mexico, Colombia	Gold	EN8	• Total water efficiency reported by year
Vedanta Resources (United Kingdom)	$6.77	India, Zambia, Australia	Alumina, copper, zinc, lead, iron ore	EN8, EN9, EN10, EN21	• Water consumption data by mine by year • Target 5-10% annual reduction in water use
Hindalco (India)	$6.45	India	Alumina	None	• None
Kazakhmys (United Kingdom)	$6.41	Kazakhstan, Tajikistan, Kyrgyzstan	Copper, zinc, silver, gold	None	• None
National Aluminum Company Limited (India)	$6.04	India	Alumina	None	• None
Eramet (France)	$5.91	Gabon, India, Indonesia	Nickel, manganese	None	• Water discharge data is presented for manufacturing sites by not mines
Randgold Resources (Channel Islands)	$5.15	Mali, Senegal, DRC	Gold	None	• None

* Market capitalization as of July 27, 2010 (Bloomberg).

**GRI Indicators are outlined in Table 3.

Source: WRI, based on public company disclosures including annual filings, sustainability reports, and websites.

ENDNOTES

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[1] The two studies indicated are: Barton, Brooke. 2010. "Murky Waters? Corporate Reporting on Water Risk." Ceres: Boston, MA and Morrison, Jason and Schulte, Peter, 2009. *Water Disclosure 2.0: Assessment of Current and Emerging Practice in Corporate Water Reporting*. Pacific Institute, Oakland CA.

[2] Australian Department of Resources, Energy, and Tourism, 2008. *Water Management: Leading Practice Sustainable Development Program for the Mining Industry.* Canberra, p. 5. Available at http://www.ret.gov.au/resources/Documents/LPSDP/LPSDP-WaterHandbook.pdf.

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[4] This is a very rough figure based on a review of over 300 years of data from mines around the world. Data varied significantly across mines; the standard deviation was 1,417 kiloliters of water/tonne of gold produced. Mudd, G. 2008. "Sustainability reporting and water resources." *Mine Water Environment.* 27:136-144. DOI 10.1007/s10230-008-0037-5.

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[17] Mudd (2008) found that while there have been some water efficiency improvements in the global mining sector, overall water consumption has increased as ore grade declined. In addition, contrary to conventional wisdom, there is no evidence that suggests that larger mines result in greater efficiency in water consumption, except for in the case of gold, diamonds, and platinum.

[18] Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov, 2007: "Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter3.pdf.

[19] James Painter. "Chile faces climate change challenge ". BBC News. Available at: http://news.bbc.co.uk/2/hi/europe/8058080.stm

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[23] Ibid.

[24] This figure includes coal and steel companies, however this paper focuses primarily on hardrock metals and mineral mining operations within the mining industry. B. Sergeant, “World’s Top 100 miners: Beyond Xstrata and Anglo-American.” Mineweb. July 2, 2009. Available at: http://www.mineweb.com/mineweb/view/mineweb/en/page67?oid=85828&sn=Detail

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[41] The 2008 and final attempt to repeal I-137 through the US Supreme Court came from Canyon Resources Corporation.

The company claimed that I-137 deprived them from property and reaping profits and therefore violates the US Constitution. The US Supreme Court upheld I-137 and denied Canyon Resources' claims.

[42] WRI. 2003. *World Resources, 2002-2004: Decisions for the Earth: Balance, Voice, and Power.* World Resources Institute: Washington, DC. p. 193.

[43] US Securities and Exchange Commission, Form 10-Q for the quarter ending September 30, 2009, p.43 http://www.sec.gov/Archives/edgar/data/1164727/000095012309054293/c91265e10vq.htm

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[45] US Securities and Exchange Commission, Form 10-Q for the quarter ending September 30, 2009, p.43 http://www.sec.gov/Archives/edgar/data/1164727/000095012309054293/c91265e10vq.htm

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[55] Examples of water footprinting tools available to the mining sector include:

- The WBCSD Global Water Tool is based heavily on GRI indicators EN8, EN9, and EN10, which comprise the basis for the tool's inputs. Although a water intensity indicator has been included (m3/ unit of product/year), the tool does not fully capture all water risks associated with the mining industry, such as dewatering pits, potentially toxic run-off and seepage from mine waste, and evaporation from water retention ponds and tailings impoundments. Further information is available at: http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?ClickMenu=special&type=p&MenuId=MTUxNQ
- The Water Footprint Network has developed a methodology for companies to calculate their "virtual water footprint" (including water impacts at a site level as well as in the transport and consumption of final products).Developed primarily for agricultural products, this water footprint methodology poses technical problems when applied to the mining sector. See http://www.waterfootprint.org/?page=files/home for more information.
- The GEMI Water Sustainability Planner Tool is designed to assist managers in translating a corporate water strategy into specific actions at the facility and site level. Based primarily on the water balance/budget approach, the tool provides an inventory of a site's water use and discharge and also helps users model the site or facility's sensitivity to changes in water supply. Available at http://www.gemi.org/water.

[56] Barton, Brooke. 2010. "Murky Waters? Corporate Reporting on Water Risk." Ceres: Boston, MA. p.9.

[57] Ibid p.78.

[58] The CEO Water Mandate is a public-private initiative organized by the UN Global Compact that assists signatory companies in the development, implementation and disclosure of water sustainability policies and practices.

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[59] Morrison, Jason and Schulte, Peter, 2009. *Water Disclosure 2.0: Assessment of Current and Emerging Practice in Corporate Water Reporting*. Pacific Institute, Oakland CA p. 51.

[60] This figure includes coal and steel companies, however this paper focuses primarily on hardrock metals and mineral mining operations within the mining industry. B. Sergeant, "World's Top 100 miners: Beyond Xstrata and Anglo-American." Mineweb. July 2, 2009. Available at: http://www.mineweb.com/mineweb/view/mineweb/en/page67?oid=85828&sn=Detail.

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[62] The mining and metals sector ranked third of all industries currently using the GRI, with 84 companies reporting in 2009. GRI, 2010. *GRI Reporting in the Mining and Metals Sector in 2009.* Available at: http://www.globalreporting.org/NR/rdonlyres/E75BAED5-F176-477E-A78E-DC2E434E1FB2/3937/GRIReportingintheMiningMetalsSectorin2009.pdf

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[64] Mudd, G. 2008. "Sustainability Reporting and Water Resources: A Preliminary Assessment of Embodied Water and Sustainable Mining." *Mine Water Environment* 27: 142-143.

[65] See endnote 55 for a description of WBCSD's Global Water Tool.