

**The Relation Between Corporate Water Risk, Water
Accounting and Financial Performance of Metal Mining Firms**

**by
Arun Raj**

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Water is increasingly being recognized as a scarce resource. Water intensive industries such as mining are progressively realizing the need and importance to judiciously and efficiently manage their water requirements. Water scarcity is a noticeable factor influencing corporate growth and performance. Although water sustainability initiatives are known to have an overall positive impact on corporate performance, there is little information on its impact on corporate financial performance.

This study focuses on business risk associated with water in metal mining industry and its impact on corporate water and financial performance. In this study a sample of 20 metal mining corporations corresponding to 244 active mines, that are a member of International Council of Metals and Mining (ICMM) were used to analyze 1) the relation between water risk and corporate water performance and 2) the relation between water performance (non-financial) and financial performance of companies? The results indicate a positive correlation between water risk and corporate water performance. Furthermore, the results did not indicate a strong correlation between water performance and financial performance of companies.

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Chapter 1: Introduction

1.1 Introduction

Water is a critical resource essential to sustain and foster life on the planet. It is also a key ingredient for industrial operations that offer various products and services integral to our modern lifestyle (Gleick 2012; WWAP 2012).

In the face of rising water scarcity, population growth, swelling urbanization and demand for more products and services, there is a surging uncertainty associated with water. Therefore, now more than ever there is an urgent need to redefine water as a communal and economic resource. That must be managed to accommodate human requirements, maintain social and environmental integrity while simultaneously ensure sufficient allocation to sustain the growing industrial requirements (WWAP 2012; World Bank 2010; Alcamo et al 2003; Lambooy 2011).

Industries now progressively recognize water as a precious resource that must be managed efficiently. Mismanagement of water can lead to innumerable business risks associated with water, particularly for industries that depend on water for their continual operation such as mining (Lambooy 2011; Gleick 2012).

Mining requires large quantities of water at more or less every stage of resource extraction. Industries such as mining that lead to environmental stock depletion and have a large ecological footprint have a competitive disadvantage and have greater exposure to water related business risks (Ceres 2009; Jenkins and Yakovleva 2006). Due to the nature of such industries they need to focus more on

the complex and often conflicting aspects of water management (Lambooy 2010; Hill 2013; Martinez 2015; Ruggie 2009).

Corporate water management although widely recognized as an essential component of corporate sustainability, is a relatively abstract concept. With loosely defined roles and responsibilities of various stakeholders involved and the indispensable role of water for human sustenance, industries can be the most vulnerable stakeholder in face of water scarcity (Gleick 2014; WWAP 2012; Martinez 2015).

Several academics have tried to distinguish and clearly define the roles of responsibilities of various stakeholders involved in managing water. Governments shoulder the primary responsibility of water allocation, use and disposal, while industries on the other hand have a responsibility to ethically uphold these regulations and respect human right to water. In practice, there is a considerable overlap between government, industry and community in managing water. This requires constant collaboration and robust strategies to facilitate and address the growing uncertainties associated with water (Gleick 2012; Martinez 2015; Lambooy 2010).

Corporate water responsibility, particularly for a resource depleting industry such as mining, needs to be conceived from a broader social, environmental and economic perspective. Economic benefits that result of water use and resource depletion must outweigh the associated social and environmental costs (Lambooy 2010; Martinez 2015; Goodland 2012; Hilson and Murck 2000).

From a business perspective, the primary role of industry is to make profit by servicing human needs (Friedman 1970). However with the advent of a new sustain-centric paradigm, industries are only now beginning to internalize social and environmental costs (Gladwin, Kennelly, & Krause, 1995). Concepts such as Corporate Social Responsibility (CSR) and Environment Management Systems (EMS) are emerging to operationalize sustainability goals (Baxter 2011; Carroll 1999). Although these concepts are known to have an overall positive impact on corporation's social performance, they lack the necessary framework to track the long-term impact on corporate financial performance (Peloza, 2009; Stanwick and Stanwick 1998; Weber 2007; Steven 2003).

The purpose of the study is to assess water risk in mining and determine its impact on corporate water and financial performance.

The remainder of this chapter contains a brief description of the problem statement, research hypothesis and questions used to analyze the relationship between water risk, corporate water and financial performance.

1.2 Problem Statement

Corporate Water Responsibility (CWR) as aforementioned is a relatively abstract concept. Its application is neither straightforward nor guaranteed (Gleick 2014; WWAP 2012; Martinez 2015). Absence of a CWR framework can open corporations to a variety of business risk associated with water that can be categorized under four key themes, namely; (1) physical, (2) reputational, (3)

regulatory and (4) financial risks (Miranda, Sauer and Shinde 2010; Gleick 2014; Mudd 2008).

Furthermore, in the absence of a clear CWR framework, corporations may choose to develop water goals from an immediate reputational and financial benefit standpoint (Hill 2013; Martinez 2015; Ruggie 2009). Given the communal interest in water use and management, short-term goals driven by immediate financial and reputational benefit might not sufficiently address the risks associated with water (Gleick 2014; Ruggie 2009).

Sustainability concepts such as CSR and EMS used to put corporate water responsibility into practice are known to have an overall positive impact on corporate performance (Baxter 2011; Carroll 1999). Studies comparing companies with and without formal CSR and EMS have concluded that the former do have a competitive advantage (Peloza 2009; Weber 2007). Various studies have also identified financial limitations as one of the key barriers towards their adoption. CSR and EMS although known to have a positive impact on overall corporate performance are not fairly equipped to quantify financial impact. This might further limit their adoption, use and advancement in modern management practices (Peloza 2009; Stanwick and Stanwick 1998; Weber 2007; Steven 2003).

Therefore, there is a need to understand and develop frameworks to quantify business risks (Hilson and Nayee 2006; Miranda, Sauer and Shinde 2010), evaluate corporate exposure and measure adequacy of corporate responses to

business risks and correlate impact of sustainability outcomes on corporate financial performance.

1.3 Research Question and Hypothesis

The primary research hypothesis is that in the mining industry, which is water intensive and site-dependent; water risk is a critical sustainability driver towards influencing better corporate water performance.

This primary hypothesis was analyzed using two research questions:

1. What is the relation between water risk and corporate water performance?
2. What is the relation between water performance (non-financial) and financial performance of companies?

1.4 Thesis Layout

This thesis contains six chapters. After the introduction, the literature review chapter presents relevant sustainability concepts, key terms and definitions used in the mining industry, water related trends in the mining industry, leading up to the water risks assessment framework used in the study. The third chapter contains thesis methodology, details about the sample, data sources and indicators used to measure business risk, corporate water and financial performance. Following which, the results chapter provides statistical analysis of various indicators used to address the research question. The fifth chapter offers discussion of results and finally the conclusion summarizes the thesis paper, identifies limitations and suggests areas for future research.

Chapter 2: Literature Review

The literature review is divided in three main sections. The first provides a general overview about global water resources, distribution and scarcity, industrial water consumption pattern and the need for corporate water responsibility. The second section reviews sustainable development, concepts such as Corporate Social Responsibility (CSR) and Environmental Management Systems (EMS), their roles and limitations in mining. Finally the third section introduces key concepts and terms in mining, water related issues and trends in mining and discusses water risk assessment framework for mining.

2.1 Water

Water, an essential resource for all life forms on the planet is widely recognized today as a scarce resource. Water is not only essential to sustain and support life but for production of all major basic human requirements such as food, energy, infrastructure raw materials, products and services (WWAP 2012).

Although water is one of the most widely available resource only three per cent is fresh water suitable for human use. Most of the fresh water is unevenly distributed and often inaccessible in the form of polar ice caps and ground water (Shiklomanov 1998). Figure 1 provides a comparison between global sector-wise water utilization. Agriculture is the largest consumer of global water resources, followed by industrial-use that comprises of almost 22 per cent of the total water resources. Industrial water use amounts to almost 60 and 10 per cent in

developed/highly industrialized nations and developing nations respectively (WWAP 2012).

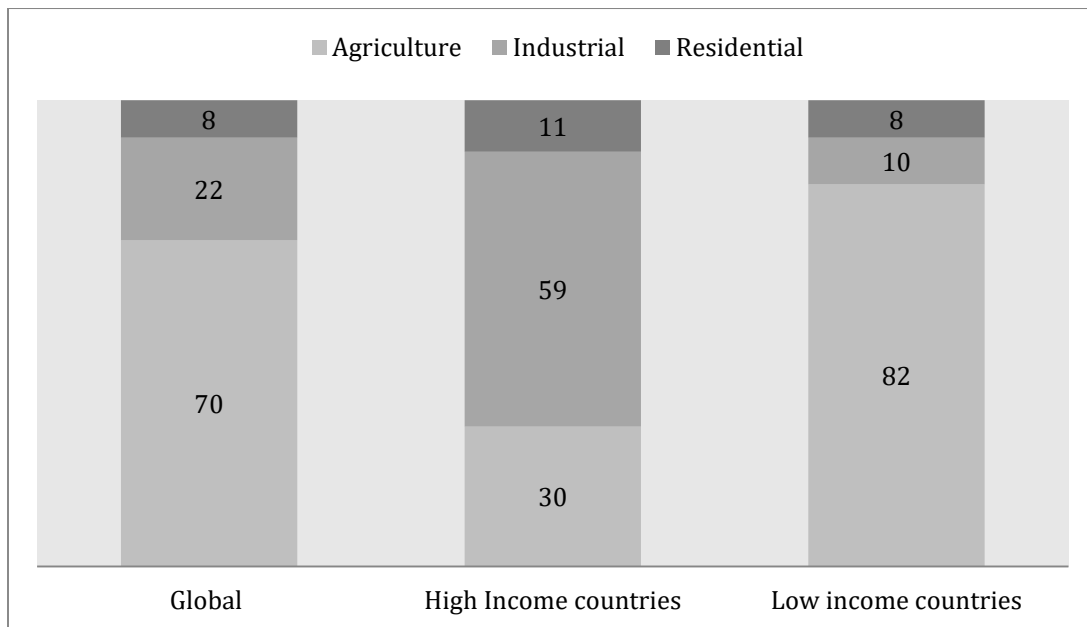


Figure 2.1: Water use per consumption category (Adapted from WWAP 2012).

Global water distribution and availability tend to influence and limit economic development particularly in areas that have large population (WWAP 2012; Alcamo et al 2003). For instance Asia has 60 per cent of the world’s population but only 36 per cent of the world’s water resources (WBCSD 2006). Figure 2 depicts the percentage of world water availability and global population and highlights the limitations of industrial growth in certain parts of the world. In contrast to developed parts of the world, developing or under-developed nations have limited water infrastructure, (recycling, treatment and distribution facilities) and financial capabilities, further complicating water management issues (World Bank 2010; WWAP 2012; Alcamo et al 2003).

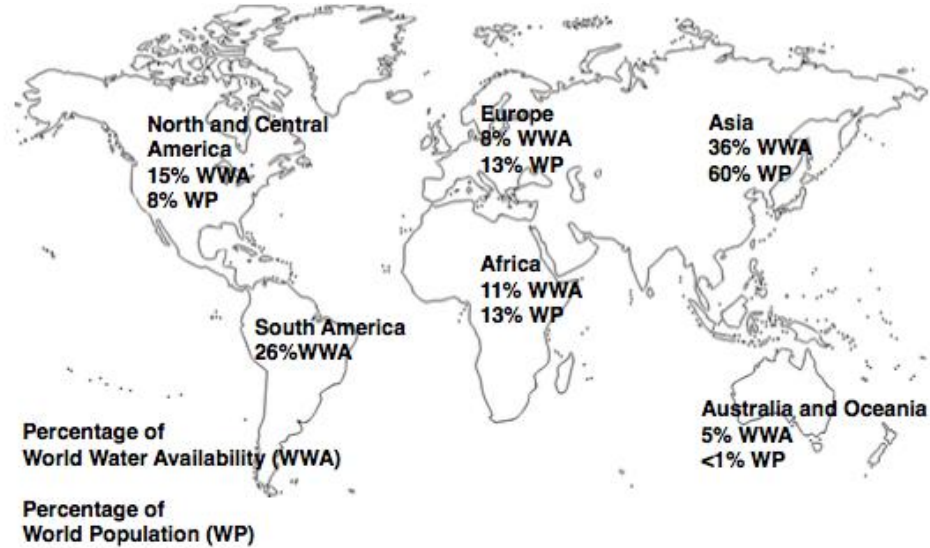


Figure 2.2: Global Share of Fresh Water Availability versus Population (Adapted from WBCSD 2006)

According to the United Nations approximately 60 per cent of the global population growth between 2008 and 2100 will be in the developing parts of the world notably Sub-Saharan Africa and South Asia (WWAP 2012). Furthermore, as we strive for higher standards of living *water footprint* of human activities increase dramatically (World Bank 2010). McKinsey and Company (2009) reported water shortage amongst primary business risks for companies with growing energy and water requirements, primarily due to the trans-boundary nature of business supply chains. Apart from physical water scarcity, the nature and mismanagement of available water frequently leads to communal, political and sometimes territorial tension and disputes (Gleick 2012; WWAP 2012; World Bank 2010).

The global context of water shortage, rising population, urban growth and demand for more products and services exacerbates the urgency of clearly defining

the role and scope of corporate water responsibility. To draw attention towards the eminent water scarcity threats in 2010, the United Nations General Assembly declared 2013 as the *'International Year of Water Cooperation'* to help build alliances and promote water cooperation between different stakeholders (WWAP 2012). Furthermore to monitor progress in global water management and report emerging issues around the world, the United Nations World Water Assessment Programme (WWAP) began publishing the World Water Development Report (WWDR) on a tri-annual basis in 2003. The fourth edition of the WWDR was released in 2012, and contends:

"Freshwater is not being used sustainably according to needs and demands. Accurate information remains disparate, and management is fragmented. In this context, the future is increasingly uncertain, and risks are set to deepen. If we fail today to make water an instrument of peace, it might become tomorrow a major source of conflict. (WWAP, 2012, p. vi)"

The aforementioned narrative of global water shortage can also be viewed as a narrow conceptualization of fresh water availability (Swatuk et. al. 2015). Current literature focuses on broadening the conceptual understanding of water. In recent years, there have been various attempts to assess global water consumption in agriculture at high spatial resolution (Hoekstra and Mekonnen 2012). Understanding the consumptive use of water is critical to encapsulate water availability and formulate strategic water policies and goals. Freshwater availability is typically limited by the passive view of 'blue water' (Swatuk et. al. 2015). Blue

water also sometimes referred to as consumptive water, is defined as volume of surface and groundwater consumed (evaporated) as a result of the production of a good. Green water refers to the sum of rainwater that has evaporated plus the amount that transpired through plants. The quantity of water that transpires through plants and results in biomass production is also referred to as 'productive green water', whereas water that evaporates constitutes 'non-productive green water' (Swatuk et. al. 2015; Hoekstra and Mekonnen 2012; Mekonnen and Hoekstra 2011).

Recent studies have tried to distinguish between the amount of blue and green water consumption in agriculture in order to highlight potential for water self-sufficiency (Swatuk et. al. 2015; Hoekstra and Mekonnen 2012). A study conducted by Rockstrom et al. (2009) on future water availability for food production concluded that most countries in theory have the potential for green water based self-sufficiency and are in a position to grow their food requirements locally. However, this requires advancement in water productivity through improving yield levels as much as four folds within the available water balance in rain-fed agriculture (Rockstrom et. al. 2009; Hoekstra and Mekonnen 2012).

Falkenmark indicator discussed in later sections is perhaps the most widely used measure of water stress. Of the 1700 cubic meter essential for human sustenance approximately 1200 cubic meters per year is available in the form of green water and is used directly for food production (Swatuk et. al. 2015). Therefore the potential for water self-sufficiency lies in broadening the use and scope of water and collaborative management practices.

2.1.1 Corporate Water Responsibility

Water is a key element for all major industries: many directly depend on it for production such as food and beverage, power generation, semiconductor, textile, paper and pulp processing, oil drilling, mining and other metals companies. The products and services offered define the urban lifestyle. Reliable water source and consistent supply are essential for businesses (Gleick 2012; WWAP 2012).

Industrial water scarcity is being recognized as a major physical risk, not only in dry parts of the world such as Sub-Saharan Africa but also in industrialized parts of North America and Europe (Lambooy 2011). Corporations are aware of the sensitivity of water scarcity and the need to safeguard investments and manage stakeholders (Lambooy 2011; Gleick 2012).

Corporate Water Responsibility is now an integral part of corporate sustainability goals. Lack of adequate access to water is known to have detrimental impact on the private sector and has been a reason for various industrial coalitions and creation of public forums to help address the problem (Lambooy 2011; Gleick 2012). Several industry water alliances and groups such as UN CEO Water Mandate, Global Water Partnership, the World Council for Sustainable Development, World Water Forum, World Water Council and the World Economic Forum's Global Agenda Council on Water are actively promoting better water management standards across sectors (McKinsey & Company 2009).

The "relationship" between corporate organizations and water resources is undergoing a major shift (Lambooy 2011; Gleick 2012; Martinez 2015). Increasingly, industry leaders in different sectors (e.g., General Motors, Ford,

Toyota, Intel, Nestlé, Unilever, and Coca-Cola) recognize freshwater as the Earth's most valuable and fastest depleting resource, and its availability dwindling at an unprecedented rate (Martinez 2015). Several academic authors and practitioners predicted this shift in industrial revolution where industries would thrive to be sustainable in their operations and have little or no negative social and environmental impact. This was envisioned as a shift in paradigm from a techno-centric worldview to a sustain-centric worldview (Gladwin, Kennelly, & Krause, 1995).

Apart from physical risk associated with lack of adequate water supply, corporations also frequently face communal backlash in regions with scarce supply or weak governance practices that are harder to quantify (WWAP 2012; Gleick 2012; Gleick 1993). The fact that corporations have open and often unrestricted access to water sources/supply (considered as a "common/public resource") and lack of transparency creates a rift between industry and *human right to water* (Gleick 1993; Gleick 2014; Lambooy 2010; Martinez 2015).

Often, it is observed that there is a thin line between the role and responsibilities between water managing authorities and corporations (Gleick 1993, Ruggie 2009). Studies conducted in the past have tried to distinguish between the roles and responsibilities of government and industries in the field of water management (Martinez 2015). Governments are expected to have regulative frameworks that govern the allocation and use of fresh water resources, whilst industries on the other hand have a responsibility of respecting human rights. In practice, this means that industrial water consumption pattern that

deprives local communities of water would lead to human rights violation, which could be grounds for corporate liability (Ruggie 2009; Ruggie 2008).

In the absence of an absolute framework for water management to address the interrelated and often conflicting goals of equity, efficiency and ecological integrity, (Gleick 2014, Lambooy 2010) many corporations focus on water management from their own interests (Chalmers et al 2012, Martinez 2015; Hill 2013). Creating a scenario where an overly techno-centric corporation (Gladwin, Kennelly, & Krause, 1995) may be incentivized to protect water from an immediate reputational and financial benefit standpoint, rather than an essential resource to sustain life (Lambooy 2010; Hill 2013; Martinez 2015; Ruggie 2009). What this implies is that corporate water responsibility needs to be analyzed from a broader social (ethical), environmental (legal) and economic (instrumental) perspective (Lambooy 2010; Martinez 2015)

Following case studies demonstrate that the integration of corporate water responsibility across the firm (i.e, in the design of governance choices, strategies and operations) is neither guaranteed nor straightforward.

Coca-Cola in India

In 2003, the local farming community from the state of Kerala, India won a case against Coca-Cola Company for over exploiting ground water resources. The High Court of Kerala state ordered permanent closure of the factory along with compensation towards the farming community. Soon after in 2008, Coca-Cola company formulated a “net-zero” user plan for India; aimed at harvesting and recharging the same amount groundwater as their operations demand in the country (Karnani 2012; Indian Resource Center 2004).

Chevron in Ecuador

Chevron a US based oil corporation has been penalized by the Supreme Court of Ecuador for USD \$ 18 billion against polluting the Amazon basin by spilling more than 30 billion gallons of untreated toxic waste regarded as negligent practice (Lobina, 2012). Final actions on the case are pending.

Disappointed due to the lack of international support over the matter the President of Ecuador, Rafael Correa launched a campaign on September 17 - 2013, called ‘Chevron’s Dirty Hands’ supported by major South American countries (CSR Wire, 2013).

Nestle in United States of America

Beverage and alcohol industry has long been a subject of public scrutiny in North America. Some of the leading companies also sell bottled drinking water that is relatively more expensive compared to piped water and consumes a lot of resources during manufacturing and transportation.

In 2009 a citizen group “Michigan Citizens for Water Conservation (MCWC)” won a case against Perrier a Nestle subsidiary in the state of Michigan. The Court ordered Perrier to reduce their water use by closing 4 extraction wells (Lobina 2012; Michigan Citizens for Water Conservation n.d).

The aforementioned case studies highlight the tendency of corporations to operate as insular entities, limited by a passive view of the role of business in society for sustainable management of water (Martinez 2015). It is also often quite difficult to establish boundaries between public responsibility and corporate liability. Therefore corporate water management is increasingly viewed as means

to ensure business validity and reducing business risk (Gleick 2012; Martinez 2015; Lambooy 2010). Corporate water responsibility targets are often ambiguous due to; (1) different legislations and policies followed in different countries, (2) water impact is different depending on the type of industry, (3) relation between industrial operations and environmental impacts are unclear and (4) complications arise usually when multinational corporations operate in countries with weak environmental regulations (Lambooy 2011). Corporate Social Responsibility (CSR) and Environmental Management Systems (EMS) (discussed in later section) are often viewed as the missing links to resolve the ambiguity associated with sustainable water management (Lambooy, 2011; Hart, 1995; Martinez 2015). Pahl-Wostl, Conca, Kramer, Maestu, and Schmidt (2013) suggest that businesses ought to play a more active role as systemic entities within a global water governance framework that encourages cooperative initiatives and stakeholder dialogues.

Apart from water abstraction, industrial discharge of various types of pollutants impact quality thereby escalating water scarcity. Industrial impact on water can be observed mainly within three management fields namely, hazardous effluent discharge, management of freshwater consumption and groundwater control management (Lambooy 2011; Miranda, Sauer and Shinde 2010). Most developed countries have regulations around environmental waste disposal that limit the disposal of hazardous waste directly into the environment. These are further bound by strict legislations that can be monitored over time (Krozer et al. 2010). However, when it comes to fresh water consumption, the relationship between environmental impact and corporations fresh water extraction and

management practices is relatively unclear (Lambooy 2011; Miranda, Sauer and Shinde 2010). Therefore promoting water efficiency alone may not be sufficient to address the complex water issues (Money 2014). There is also a necessity to ensure equitable access to clean water so that society can enjoy food security, basic sanitation, and ecological integrity (Pahl-Wostl et. al 2013; Gleick 2012).

The United Nations defines Sustainable Water Management (SWM) as corporate management practices that help (1) reduce freshwater requirement for business operations, (2) improve water- use efficiency across their supply chain and in raw material productions and (3) improve community access to freshwater and services (WWAP 2012). These can range within corporate EMS and CSR strategies and are often jointly viewed as a part of the corporation's sustainability initiatives (WWAP 2012; Lambooy 2011). EMS is viewed as more technical management of environmental impact and widely follow the 'ISO 14001' certification process to audit the corporations performance (Lambooy 2011; Marinova et al., 2006). The most commonly followed guideline for CSR strategies is the 'OECD Guidelines for Multinational Enterprises' (OECD Guidelines 2000; Lambooy 2011). Companies often also follow their own standards when it comes to CSR (Lambooy 2011; Money 2014). The levels of detail and commitment differ per guideline, however in general certified EMS requires more commitment than meeting CSR requirements (Lambooy 2011; OECD Guidelines 2000).

According to Martinez (2015) *"The ultimate goal of corporate water responsibility is that companies contribute to ecological integrity via the efficient and equitable abstraction, usage, and disposal of water resources."* Keeping with the

aforementioned case studies, in the absence of a robust corporate water strategy, corporations open themselves to a myriad number of water risks that could potentially impact business operations. Following section details key water risks and its impact on operations and corporate financial performance.

2.1.2 Corporate Water Risk

Often corporate water responsibility strategies are a reflection of anticipated water-related business risks (Gleick 2012; McKinsey & Company 2009; Money 2014). Water related business risks may include but not limited to, (1) physical, (2) reputational, (3) regulatory and (4) financial risks (McKinsey & Company, 2009). Gleick (2012) elaborates that SWM strategies are driven by five primary motivations; (1) to ensure companies social and legal license to operate, (2) preventing operational crises due to inadequate freshwater, (3) ensuring profitable future for current and future businesses and supply chains, (4) upholding corporate values and (5) gaining competitive advantage.

Physical Risk

Physical risk includes the possibility of operating in conditions such as ‘too little’ (scarcity) or ‘too much’ (flooding). Decline or disruption in physical availability of water has direct impact on industrial operations and production of raw materials. In case of flooding, the likelihood of water contamination increases thereby increasing costs of treatment and filtration.

Reputational Risk

Reputational risk stems primarily from stakeholders perception of corporations management practices and operations. This can lead to reduced investor confidence, conflict with local communities, associated impact on brand value and in certain cases as aforementioned adverse regulatory responses.

Regulatory Risk

Regulatory risk includes subliminal legal performance that might have repercussions in terms of the company's license to operate in the region. In certain cases changing environmental conditions or disharmony in local community groups might put pressure on the local municipalities and politicians to reevaluate and alter corporation's license and access to freshwater.

Financial Risk

Finally, any change in water quality or policies to promote greater efficiency can lead to new and costly requirements on corporation's water management practices. This is perceived as financial risk associated with water scarcity. Disruption in operations and resultant loss in revenue due to any of the aforementioned risks has a direct impact on the company's financial performance (Gleick 2012; Ceres 2009; Money 2014; Miranda, Sauer and Shinde 2010).

2.1.3 Corporate Water Responsibility Approach

Corporate water responsibility strategies are quite diverse and different depending on the corporations sector, operating region, values, level of social engagement and freshwater requirement amongst other factors (Gleick 2012;

McKinsey & Company 2009; Ceres 2009). They usually take into consideration water quantity (abstraction), quality, stakeholder expectations and existing/future regulations (Gleick 2012; Ceres 2009). Key factors that determine the extent and type of risk on any given business can be categorized as internal and external factors.

Internal factors depend on the companies' own water management performance and requirements (Gleick 2012). It extensively depends on the age of environment management system (Ceres 2009; Davison 2001). Industries that have a higher ecological footprint, for instance mining that rely on chemical wash/treatment have a competitive disadvantage (Ceres 2009; Jenkins and Yakovleva 2006). Due to this risk exposure they tend to focus more on internal processes to reduce their ecological footprint and monitor water quality in their processes (Jenkins and Yakovleva 2006). Other internal factors include the nature of water use and discharge. Certain industries might require large quantities of water mainly for cooling purposes therefore are not concerned with its quality whilst others for instance; semiconductor industry might require the same amount of water however of very high quality. For this reason they tend to rely on initiatives to maintain and improve the quality of water within their operating region (Gleick 2012; Ceres 2009).

External factors are often not under the corporation's domain. These include risks due to existing hydrological conditions, the amount of fresh water available in any region. Geographical positioning of the industry; industries operating close to an ecological hotspot, or close to agricultural lands etc. have higher social and

regulations pressure (Gleick 2012; WWAP 2012). Political stability and local municipalities performance is also a major external factor. Underperformance of local municipalities is commonly observed in global south that may lead to disruption in water availability and quality. As discussed in the earlier section, any form of disruption of water availability for local communities can be held as corporate liability (Gleick 2012; Pahl-Wostl et. al. 2013).

2.1.4 Water as Economic Good

In 1992 the Dublin Water Principles claimed “water as an economic good” for the first time in a UN setting (Rogers et. al. 2002). As aforementioned, there is a thin line between the role and responsibilities between water managing authorities and corporations (Gleick 1993, Ruggie 2009). From an economic perspective, water pricing is probably the simplest method to promote equity and efficiency. However, it is also often one of the most politically difficult route to water sustainability (Rogers et. al. 1998).

A common problem with most municipalities across the world is that prices and tariffs are almost always below the full-cost of supply. As an essential necessity for human sustenance, the most important goal for municipalities is to ensure human access to water. To which they are often burdened with large inefficiencies and increased demands. Increasing water tariff has six generally accepted effects i.e (1) demand reduction, (2) improved supply, (3) potential to re-allocate between users, (4) improved managerial efficiency due to increased revenue, (5) increased price leads to sustainability and (6) increased cost leads to lower per unit cost and access

of water for poor (Rogers et. al. 1998; Rogers et. al. 2002). Given the benefits of increasing water cost and tariff, governments have an incentive to move away from the role of 'provider' and step in as 'regulator', promoting private sector participation in water services (Savenije and Van Der Zaag 2002). However this is often perceived as governments trying to relinquish responsibilities and is met with a lot of public opposition. The primary public concern is the potential to abuse the resource for vested corporate interests (Savenije and Van Der Zaag 2002; Rogers et. al. 2002).

Furthermore there is ambiguity with regard to the exact definition of full-cost pricing. Including economic externality costs and environmental externality costs require holistic management of resource and collaboration between all stakeholders. Water policies must encourage consumers to adhere to pricing schemes (Rogers et. al. 2002). This requires integrated water resource pricing that includes water prices, sewerage prices, additional charges for effluents and differential industrial abstraction charges. Unfortunately both in the developed and developing world there is a large gap between conceptual integrated water resource planning and how water resource planning are actually done (Rogers et. al. 2002; WWAP2012)!

2.2 Sustainable Development

The Brundtland report (WCED 1987) stated one of the most commonly used definitions of sustainable development: *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*

In the area of environmental sustainability, the report is more specific: *“sustainable development does imply limits—not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities”* (WCED, 1987).

As aforementioned, the new sustain-centric paradigm situated between the techno-centric and eco-centric paradigm, brought with it a shift in corporate environment and social management. Promoting concepts of inclusion of marginalized groups, stakeholder engagement, future generations and pollution abatement amongst others. (Gladwin 1995; Hart 1997). Concepts such as Corporate Social Responsibility (CSR) and Environment Management Systems (EMS) emerged as modern practical management practices to help strategically manage the social and environmental impact of industries (Porter and Kramer 2006; Davison, 2001). Growing environmental concerns amongst stakeholders propelled industries to ethically re-evaluate their practices and go beyond legislations to improve their portfolio. This triggered re-evaluation of traditional end-of-pipe environmental solutions and looking at prevention mechanisms that promote innovation and reduce waste production (Hart 1995).

2.2.1 Environmental Management System (EMS)

EMS is a formal system for formulating goals, comparing options, gathering information, making choices, monitoring and improving overall performance (Davison 2001). Some organizations have developed internal processes and

techniques to monitor environmental impact whilst others have adopted existing more formal EMS practices. Whatever approach has been adopted, the elements of EMS (legal and other requirements, environmental aspects, structure and responsibility, training, awareness and competence, communication and documentation) remain the same (Baxter 2011). It helps organizations identify and evaluate their environmental impact and assess its significance based on local conditions of operation and stakeholder expectations, which is one of the most difficult parts of environment management (Baxter 2011).

EMS helped change the perspective that environmental management is not necessarily bad for the company's profits, instead can have a positive impact on the business itself (Steven 2003). Several studies comparing organizations with and without a formal EMS concluded that the former tend to perform better, are more efficient and competitive (Weber 2007).

The effectiveness of EMS depends on three primary variables; the age of EMS, resources available and nature of the organization. Lack of resources and financial constraints are sometimes barriers towards adoption of a more formalized EMS (Steven 2003). Self-commitment is one of the most influential factors that promote adoption of EMS within an organization with an assumption that it is beneficial and rewarding in the long run (Weber 2007).

Keeping with the United Nation's definition of Sustainable Water Management discussed in section 2.1, an effective EMS could potentially influence fresh water requirements and improve water-use efficiency (WWAP2012), by

reducing raw material consumption, treatment and disposal costs associated with water (Lambooy 2011; Marinova et al., 2006).

From a mining perspective, a study conducted by Hilson and Nayee (2006), examining business practicality of integrating EMS into mining and related operations concluded that EMS is critical for the mining sector. EMS can enable companies to sufficiently allocate necessary resources for environmental concerns and ongoing evaluation of practices and procedures will ensure ethical social performance. The study also concluded that shortage of financial resources is amongst primary limitations in adopting and improving EMS in developing parts of the world such as Africa (Hilson and Nayee 2006).

2.2.2 Corporate Social Responsibility (CSR)

The concept of corporate social responsibility can be traced back to early 1950s. Traditionally based on the underlying assumption that business is a singular entity with a sole motive of increasing economic growth (Friedman 1970). Thus, the traditional view of CSR is mainly about profit, compliance and philanthropy. However, in 1970s the concept evolved to a broader and more stakeholder oriented concept (Caroll 1999).

The modern idea of CSR entails that business and society are interrelated. Concepts and terms such as Business Ethics, Corporate Citizenship, Sustainability, Corporate Environmental Management, Business and Society, Business and Governance, Business and Globalization, Stakeholder Management, Governance are often used interchangeably with CSR (Matten and Moon 2008).

Carroll (1999) proposed businesses have four kinds of primary responsibilities i.e (1) economic, (2) legal, (3) ethical and (4) philanthropic. The economic responsibility refers to a corporation's economic productivity since it is the primary objective of any business. Adhering to legal regulations and frameworks constitutes a corporations legal responsibility. Ethical responsibility refers to the obligation of doing the right thing, ensuring that all business operations are within ethical bounds, regardless of legal requirements. Finally a company's philanthropic responsibility comprises of social engagement and involvement with local issues that may or may not be directly related to business.

Although CSR now is a very common concept and practiced across sectors, there is no accepted universal definition. According to the European Commission (2001) CSR is defined as *"a concept whereby companies integrate social and environmental concerns into their business operations and in their interaction with their stakeholders on a voluntary basis."*

2.2.3 Limitations of EMS & CSR

EMS and CSR are known to have an overall positive impact on corporations. However, their financial impacts are loosely based and unclear. The nexus between corporate social/ environmental and financial performance is subjective to various factors such as firm size, industry, economic conditions, and regulatory environment (Griffin and Mohan 1997; Pelozo, 2009; Ameer and Othman 2012; Stanwick and Stanwick 1998).

Some studies argue that EMS lacks the framework to accurately quantify the impact on the corporation's financial performance. A study by Kevin Watson comparing financial performance of EMS adopters and non-adopters concluded that there is only a marginal difference between them. He explained two possible hypotheses; that the financial resources required to set-up EMS probably outweighs the benefits or that the current accounting practices lack the ability to measure financial benefits due to EMS (Kevin, 2004).

CSR is known to have a positive impact on a company's social (Corporate Social Performance CSP) and financial performance (Stanwick and Stanwick 1998). A compilation of available studies by Pelozo (2009) concluded that as high as 62 per cent of studies indicated a positive relation between CSR and CSP and financial performance, while 15 per cent of the studies reported a negative relationship. However, in order to develop accurate indicators to monitor the relationship between CSR and corporate financial performance, it is imperative to determine how corporate social performance creates business value (Ameer and Othman 2012; Pelozo 2009; Stanwick and Stanwick 1998).

As discussed in the earlier section, water is a critical communal resource. Any impact on local water resources could directly impact and influence local communal perception towards business operation causing the change (Gleick 2012; Ceres 2009). By the same logic, any positive impact on water resources by means of efficient operations management (EMS), or communal projects (CSR) could also result in increased societal value towards the business entity. Thereby there is a

likelihood that positive influence on societal perception could reflect in a corporation's financial performance.

A study conducted on Weber et. al. 2005, comparing 100 companies on the relationship between corporate non-financial sustainability and financial performance concluded a net positive relation. The study was based on the hypothesis that corporate environment and social performance are influential sustainability drivers that impact sustainability outcomes and positively impact the overall financial performance (Weber et. al 2005).

2.2.4 CSR and EMS in Mining

Mining activities (discussed in later section) have the potential to impact diverse groups of environmental entities, and are of interest to a wide range of stakeholder groups. Although mining may result in considerable economic benefits, job creation and revenues, there are several serious local concerns related to water quality and quantity (Mining, Minerals and Sustainable Development 2002). Failure in addressing local concerns can result in public backlash and sometimes in operational risk. Following case study of a Canadian Gold mining corporation in Greece is an example to highlight CSR needs in mining.

Eldorado Gold

Eldorado Gold is a Vancouver based low-cost gold producer with over 20 years of experience building and operating gold mines. They currently have development and/or exploration operations in Turkey, China, Greece, Romania and Brazil (Eldorado Gold 2015).

Recently the company has been facing severe public backlash in Greece from the new government over the company's gold mine plans. Eldorado, one of the largest foreign investor in Greece will help boost the country's sluggish economy. Eldorado entered Greece through the \$2.5-billion purchase of European Goldfields in late 2011. The company hopes to invest another \$450-million to convert their current open-pit gold and copper mine into an underground colossus that will produce 140,000 ounces of gold a year. However, the company's position in Skouries, Greece is quite polarized. Some local members of the government and community are keen to allow expansion of the mine whilst others are against privatization of natural resources, anxious about the environmental impacts and concerned about the local water (*aquifer*) resources. Kostas Katsifarakis, a civil engineering professor at the Aristotle University based on a mine impact assessment study states, '*The carrying capacity of the region will be exceeded by far,*', referring to the ground water aquifer source for the gold mine. Aside from tourism, farming, animal husbandry, fisheries and beekeeping, it helps maintain the livelihoods of the region, all of which depend on a clean environment and well-functioning ecosystems (Globe 2015).

According to a post on the company's website on February 27, 2015, approvals required to complete final construction of the processing plant at the Skouries project have been revoked by the Greek Ministry of Productive Reconstruction, Energy and Environment (Eldorado Gold 2015).

Company-community relations are hence at the heart of sustainable development in mining. CSR can aid in facilitating a dialogue and on-going tri-partnership with government, civil societies and small-scale businesses to ensure

stakeholder interests are amongst the top priorities for the company (Hamann 2003).

To foster better stakeholder relationship particularly with local communities and operationalize CSR in mining, Robert Goodland (2012) formulated eight principles that mining corporations must follow:

Principle 1: Social and Environmental Assessment: Many countries have legal requirements for mining corporations to assess social and environmental conditions prior to any formal clearance, commonly termed as ESIA (Environmental and Social Impact Assessment). ESIA helps mining corporations internalize social and environmental costs and must present the company's impact mitigation strategies.

Principle 2: Transparency vs. Secrecy: All ESIA reports (Impact/Compensation Contract, to restoration, rehabilitation, and monitoring) should be freely available to local communities. Citizen groups and local stakeholders should actively participate in this process to ensure transparency.

Principle 3: Acceptance by Stakeholders: Mining corporations must ensure that all stakeholders (including mining company employees, local communities and residents, and the government units that receive taxes, royalties and grant permits, as well as the stockholders and managers of the company) are in agreement for the mining project because the risks are slight; compensation is great; and job training, employment, and local procurement are attractive.

Principle 4: Food Production Trumps Questionable Mining: Under any

circumstances mines must ensure that they do not pose any local threat to community sustenance in terms of land and water resources.

Principle 5: Compliance with International Standards: Corporations must ensure compliance with all local and proponent's home countries regulations. An emerging goal of CSR is to ensure 'Social License to Operate (SLO)', a dynamic process that ensures stakeholders actively contribute and support mining activities.

Principle 6: Prequalification or Certification of Potential Mining Permit Seekers:An independent certification process lead by local governments to filter companies with weak CSR and EMS practices.

Principle 7: Insurance and Performance Bonds Principle: Mining corporations just as any industry that requires high capital for infrastructure depend on insurance bonds. Performance bonds must be kept high enough to ensure coverage for any future accidents / non-compliance and long-term environmental remediation post mine closure.

8: Royalties, Taxes and Fees:Responsible miners must ensure that the net benefit meaning profits, benefits etc. minus the environmental and social impacts should be identified and allocated.

Aforementioned principles ensure the social benefits of mining especially from a local perspective outweigh the environmental costs that are not internalized by businesses. This can be better understood by the concept of weak and strong sustainability discussed below.

To contribute to sustainable development, mining corporations must ensure all adequate measures are being undertaken and explored to minimize their environmental impact across all the critical mining phase i.e, exploration, extraction and refining to reclamation. Mine management should adopt Cleaner Production (CP) preventing strategies to minimize pollution, impact of products and by-products on the environment (Hilson and Murck 2000). This can be a challenge of monumental proportions, since mining follows a model of “weak sustainability” that allows trade-offs among economic, social, and environmental responsibilities (Goodland 2012) as will be explained in the following section.

Weak and Strong sustainability concept can be understood by visualizing man-made and natural resources and stocks. Stock flow of natural and man-made resources result in business products and services. Strong sustainability, a concept favored by many ecological economics follows the principle that man-made and natural goods are not interchangeable. Furthermore, all natural capital must be conserved or restored at the end of the business cycle. Weak sustainability on the other hand maintains inter-changeability of natural and man-made goods and allows trade-offs among environment, social and economic stocks. Certain natural resources will and always be depleted at the end of the business cycle (Neumayer 2003; Goodland 2012).

Mining as an extractive industry will always lead to natural resource depletion. Therefore in order to be sustainable, economic benefits of extracting natural resources should outweigh all environmental and social costs (Goodland

2012). The following section contains direct quotes from Goodland 2012, elaborating the limitation of sustainability in the mining sector from an ecological perspective and highlighting the need for superior EMS and CSR standards.

The Non-Sustainability of Mining (Source: Goodland 2012).

“Mining is an extractive industry, hence inherently depletes a stock resource. Metal recycling and efficiency can postpone exhaustion, but cannot make mining sustainable. Under the concept of “weak or quasi-sustainability,” mining can be considered to contribute to sustainable development if its economic benefits outweigh social and environmental costs, and if mining revenues are invested in building sustainable industries, enterprises and productive capacities.

The “weak sustainability” principle posits that different forms of capital (natural, human, physical) are substitutable, although, in fact, the substitutability among them is not great. Activities can be considered “sustainable” if the overall stock of capital is at least not diminished and preferably augmented. This definition suggests that mining can contribute to sustainable development, but only if it gives rise to long-term net benefits (environmental, social, or economic) that equal or exceed the values that existed prior to exploitation. To arrive at the “net”, all social and environmental costs and all external costs must be subtracted from the benefits. Since these costs are rarely accurately calculated, it can be hard to claim a positive net value. In addition, the ‘trickle down theory’—that some fraction of the benefits accrued by the recipients of royalties, profits, and taxes eventually trickle down to the impacted people—is aspirational.”

2.3 Mining and Water

Mining often requires large quantities of water. However, compared to other sectors such as agriculture, mine water use is relatively subliminal. For instance mining accounts for only 1 per cent of water use in the United States (Joan et al 2009). Even in mining intensive water scarce countries such as Australia and Chile, mining activities account for only 1.2 and 5 per cent respectively (Tejos and Proust 2008; Pink 2010).

However, its impact on the local watershed (both quality and quantity) is severe and often amongst the key reasons behind communal opposition towards mining. Following sections lists some of the key water related issues in mining. Some fundamental mining concepts and definitions have been listed in Appendix 1.

2.3.1 Water-Related Issues in Mining

From a *watershed* perspective, mining is a large water user and therefore may impact water availability for other purposes. In addition to large water consumption, mining also can significantly impact the local water quality. Acid rock drainage, leaks from tailings and waste rocks or direct disposal of tailings into local water can seriously contaminant ground and surface water (Mining, Minerals and Sustainable Development 2002; Miranda, Sauer and Shinde 2010; Mining Association of Canada 2004). Water-related issues in mining can be categorized in two major categories, water quantity and quality.

Water Quantity

Water requirements primarily depends on the scale of production, ore grade, technology or processes involved and the commodity being mined. Most of the water is used for grinding, separating minerals from host rocks/ore, washing transportation, solvent, dust control and cooling (Miranda, Sauer and Shinde 2010).

In general, extracting and processing lower ore grade requires more water. Noble metals even in low concentration (ore grade) are economically viable to extract compared to base metals and therefore result in large variation in water use between different minerals. Typically gold, platinum, diamond, nickel and copper are associated with higher water consumption (Mudd 2008; Miranda, Sauer and Shinde 2010; Mining Association of Canada 2004).

Norgate and Lovel (2004) and Mudd (2007) undertook comprehensive studies to quantify water consumption for several commodities. Table 2.1 provides an estimate of water consumption (including recycled water) for various commodities. Both studies stated that ore grade and extraction processes/technology, are not necessarily uniform across the industry. Therefore, estimated water consumption rates would not be fairrepresentation to compare water performance between different companies (Noorgate and Lovel 2004; Mudd 2007). Mudd found that generally water consumption per tonne ore processed was lower for larger tonnage operations than smaller tonnage operations and attributed this relationship to economics of scale (Mudd 2007).

Table 2.1: Mudd's Estimate of Water Consumption, Including Recycled Water
(Adapted from Mudd 2008)

Commodity	Sample Size	Ore Processed (e.g. m ³ /t ore)	
		Average	SD
Bauxite (m ³ /t bauxite)	17	1.09	0.44
Black Coal (m ³ /t coal)	18	0.3	0.26
Copper (m ³ /t ore; m ³ /t Cu)	48	1.27	1.03
Copper –gold (m ³ /t ore; m ³ /t Cu)	42	1.22	0.49
Diamond (m ³ /t ore; m ³ /carat)	11	1.32	0.32
Gold (m ³ /t ore; m ³ /kg Au) - Total	311	1.96	5.03
Gold (m ³ /t ore; m ³ /kg Au) – outlier removed	306	1.372	1.755
Zinc + lead + silver + copper + gold (kL/t ore; kL/t Zn + Pb + Cu)	28	2.67	2.81
Nickel(sulfide)(m ³ /t ore;m ³ /t Ni)	33	1.01	0.26
Platinum group(m ³ /t ore;m ³ /t PGM)	30	0.94	0.66
Uranium (m ³ /t ore; m ³ /t U3O8)	24	1.36	2.47

Water Quality

As aforementioned water quality concerns are more severe and raise local concerns about mining operations. Due to the mobile nature of water there are higher risks of toxic ground contamination (seepage), leaching and surface water

contamination. Typically most of these threats are limited to the local watershed, in some cases regional, depending on the geological conditions (Mudd 2008; Miranda, Sauer and Shinde 2010).

Water contamination can pose serious human health and future economic issues. Toxic land contamination can render it unsuitable for agriculture purpose and consumption of toxic water can seriously affect animals and humans in the vicinity (Mudd 2008; Miranda, Sauer and Shinde 2010). While most companies are mandated to adhere to strict environmental laws that limit contamination risks associated with mining (Mining, Minerals and Sustainable Development 2002; Mining Association of Canada 2004), water quality remains to be a cause of major concern amongst local stakeholders (Miranda, Sauer and Shinde 2010).

2.3.2 Water-Related Trends in Mining

Water availability and quality concerns are likely to increase in the near future due to the following reasons:

Rising demand for mined products: Global demand for mined commodities have been steadily increasing in the industrialized world. With population growth, more and more people are migrating to urban areas that depend on availability of mined product (Miranda, Sauer and Shinde 2010). Approximately, 60-80 million people are added to cities every year. That is equivalent to the population of France and Germany combined (Raw Materials Group 2012). Mined products currently contribute to approximately 11.5 per cent to global GDP. Coupled with its indirect

impact on agriculture, transport and construction it amounts to almost 45 per cent (Mining Weekly 2012).

Activities are growing in countries with scarce industrial water availability: South American and Asian countries—especially China and India have dramatically increased mining activities and support a relatively large population with limited water resources as discussed in section 1. To continue developing their mining portfolio they must focus on higher efficiency standards to avert any water crisis (Miranda, Sauer and Shinde 2010).

Globally declining ore grade: Global ore grades especially for precious metals have been steadily declining (Mudd 2008). Production of low ore grade results in less per unit production of metal and minerals and require greater quantities of water (Mudd 2007), resulting in higher waste production (Miranda, Sauer and Shinde 2010).

Climate change: Climate change induced rainfall changes and flash floods are now a common occurrence in several parts of the world (WWAP 2012). Flooding can increase chances of water contamination at a mine site (Mudd 2008). As aforementioned, lack of reliable water source and availability is a primary business risk associated with water.

In the face of unprecedented global urbanization, demand for mined products is only likely to increase. Consolidated impact of increased demand and aforementioned water-trends in mining is only likely to exasperate water related issues associated with mining.

2.3.3 Water risk in Mining (Assessment Framework)

As discussed in Section 1.2 there are four types of business risks associated with water, namely physical, reputational, legal and financial. These risks are already being observed in the mining industry.

Physical water risk is a major threat in arid and semi-arid regions such as Chile. Companies are forced to look for alternate sources of water. Companies with large operations in Chile such as BHPBilliton and Codelco are now operating and managing independent desalination plants to ensure consistent water supply in case of any disruption (Tejos and Proust 2008; Billiton 2013; Codelco 2013). Physical water risk also extends to quality of water available for mining use. Low water quality can lead to loss of mineral recovery or reduced product quality thereby affecting the company's production and financial performance (Mining, Minerals and Sustainable Development 2002). Mining intensive water scarce countries such as Australia and Chile are increasingly imposing stringent regulations on the mining sector to ensure efficient water management. For instance Xstrata's largest copper mine in Chile was asked to reduce its water extraction rate to 300 liters a second from 750 in 2010. Such legal requirements to reduce consumption can be expensive measures to comply and can be categorized as financial risk (Miranda, Sauer and Shinde 2010).

A company's exposure to water risk is very subjective, depending on the geography of its operations, the geological characteristics of the ore bodies being mined, the climate and the type of operations. Anticipating future risks not only aid

in averting losses and costly solutions, they also build investor confidence who may not have the technical expertise to quantify such risks (Miranda, Sauer and Shinde 2010). From this perspective, specific questions need to be better addressed in company reporting that aid in risk assessment, such as: Does the company assess impact on local communities? Does the company measure water source sustainability? Does the company monitor potential water contamination points like waste rock/tailings? What percentage of the company is operating in water scarce region? Has the company developed an adequate future plan for water supply? Does the company assess potential impact of climate change on its operations? Does the company report its water discharge practices? Does the company report quality of waste being stored in tailings and other storage facility?

To assess risk exposure, Water Resource Institute developed a water risk assessment framework for the mining sector presented below in Table 2.2 (Miranda, Sauer and Shinde 2010; Morrison et. al. 2009).

Table 2.2: Water Risk Assessment Framework (Source: WRI 2003; Morrison et. al. 2009, pg9)

Questions for Companies	Surrounding Environment	Type of Commodity	Type of Operation	Corporate Policy Approach	Disclosure/Engagement	Regulatory Climate
	Operating in water scarce region? Competing with other users?	Grad of ore and ratio of ore to final product	Extraction method, waste disposal, water management procedures?	Does the company conduct water footprint analysis? How are water tests 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
	Low
	Medium

Unlike other industries, mining is a site dependent sector. A company with exemplary standards of operations may be expected to be risk averse, however from a mine-site (watershed) perspective, whether their operating standards meet local water demands will depend on the extent of water scarcity/availability and number of competing users (Miranda, Sauer and Shinde 2010). Table 2.2 provides a risk assessment framework, quantifying level of risk for six distinct categories. These categories include local site feature (rainfall), mine feature (type of operations, commodity), corporate involvement (water policy, level of engagement, disclosure) and finally government involvement (legislations) in the process of mining. Water risks such as physical, reputational and regulatory discussed in section 1.2 are a factor of surrounding environment, corporate policy approach and regulatory climate listed in Table 2.2.

2.3.4 Water Accounting Frameworks

For the aforementioned reason, water accounting in a mine site should consider local water availability and needs. Several new accounting frameworks such as the GEMI Water Sustainability Planner Tool and Minerals Council of Australia (MCA) Water Accounting Framework are built from a watershed perspective. Some companies such as Newmount Mining, BHPBilliton and Rio Tinto have developed internal frameworks that provide site-specific assessment and

management.

These new accounting frameworks take into account, local precipitation, map existing water conveyance network, estimate waste production, highlight vulnerable areas to water contamination and estimate *run-off* that may affect the local watershed etc. These new frameworks allow company's to accurately map water risks and set future targets.

2.3.5 Corporate Reporting

Mining sector is known to follow the best overall sustainability reporting practices, particularly when it comes to water. A benchmarking study on state of water disclosure by Ceres compared 100 publicly traded companies from eight different sectors and concluded mining amongst leaders in corporate water reporting. Mining scored highest overall (Ceres 2009). This perhaps indicates the industry's exposure to water risk.

However reporting practices are not consistent within the industry. A study conducted by the Water Resource Institute on water-related disclosure practices concluded that South African and Latin American companies often reported most water-related information, whereas most Chinese and Indian companies reported little or no information (Miranda, Sauer and Shinde 2010). In the absence of a global framework on accounting water risk and reporting corporate water performance, it is challenging to fairly compare corporate environmental and social performance.

While there is no agreed upon reporting structure, Global Reporting Initiative (GRI) is the most commonly used guideline globally. Following section provides water indicators listed under GRI.

GRI Indicators

The Global Reporting Initiative (GRI) is a multi-stakeholder process and independent non-profit organization whose mission is to develop and disseminate globally applicable ‘sustainability’ reporting guidelines. These guidelines are for voluntary use by organizations for reporting on the economic, environmental, and social dimensions of their activities, products, and services (Global Reporting Initiative 2006).

GRI water indicators are roughly consistent with the aforementioned definitions. Following are the voluntary and mandatory GRI water indicators (see Table 2.3):

Table 2.3: List of GRI Water Indicators (Source: Global Reporting Initiative 2006)

GRI Indicator		Requirement
EN8	Total water withdrawal by source	Mandatory
EN9	Water sources significantly affected by withdrawal of water	Voluntary
EN10	Percentage and total volume of water recycled and reused	Voluntary
EN21	Total water discharge by quality and destination	Mandatory
EN25	Water sources and related habitats significantly affected by discharge of water	Voluntary

Within the five aforementioned GRI indicators, only EN8, EN10 and EN21 were consistently reported. EN9 and EN25 were typically reported as per company's internal definition of 'significant'.

Reporting Limitation

As discussed in the beginning of this section, there is no agreed upon reporting structure and disclosure largely varies within the mining industry. However from a watershed perspective there are three critical limitations with water disclosure in mining:

1. **Mine-Site Level Information:** Most of the GRI water indicators listed above are typically reported on a corporate level. As discussed in the previous section, water-related issues in mining are primarily from a local watershed perspective. Overall water mining water use is relatively subliminal. Furthermore, water quality concerns are often more severe compared to water quality concerns. Current water disclosure practices highlight little or no information on possible contamination, impact and prevention strategies.
2. **Contextual Information:** Keeping with the aforementioned limitation and aforementioned sections on corporate water responsibility; businesses have an ethical responsibility to support local community. Any business operation that deprives local communities of water would lead to human right violation (Ruggie 2009; Ruggie 2008). Water disclosure provides little or no information on local community; local water demands and strategies to ensure local needs are not being curtailed.

3. Reporting Consistency: Lack of consistency in calculating methods, reporting formats and explanation across companies limits the possibility to compare performance, regulate and set standards.

Chapter 3: Methods

3.1 Introduction

This chapter contains the methodology used in the study. The main purpose of the thesis was to determine water risk associated with mining, and evaluate whether it impacts corporate water and financial performance. This was done using quantitative data analysis. Water risk was calculated based on mine site features using seven nominal indicators discussed later in this chapter. Correlation between water risk, corporate water and financial performance was analyzed using statistical analysis using three primary indicators for corporate water and three for financial performance. Publicly available secondary data was used to analyze 20 mining companies corresponding to 244 active mine sites.

The primary research hypothesis was that in the mining industry, which is water intensive and site-dependent; water risk would be a critical sustainability driver towards influencing better corporate water performance. Furthermore, better corporate water performance might lead to higher financial performance. The nature of the hypothesis was influenced by concepts such as corporate water responsibility and water related risks in mining, discussed in the previous chapter (Section 2).

This chapter provides, the research questions, description of the sample selection, the water risk assessment framework used to categorize and quantify risk, as well as indicators used to measure corporate water performance and finance performance used in the study.

3.2 Research Questions

This study focuses on two research questions:

1. What is the relation between water risk and corporate water performance?
2. What is the relation between water performance (non-financial) and financial performance of companies?

3.3 Sample Selection

Member companies (twenty at the time) of the International Council for Mining and Metals (ICMM) were selected for the purpose of this study. Since 2014 two new corporations have joined the council and are not a part of the study. The selection ensured a sample of companies with similar values. All ICMM members are required to implement the ICMM Sustainable Development Framework and must include and adhere to 10 principles (Appendix 2) and six supporting position statements in their corporate policy. ICMM Sustainable Development Framework includes concepts such as: stakeholder inclusion, water catchment based planning and effective water resource management (ICMM 2015).

Table 3.1 contains a list of companies used in the study and their corresponding active mine sites. The total sample consists of 20 companies and 244 mine sites.

Table 3.1: Companies and active mine site (Sample)

Company Name	No of active mine sites
Teck Resources Ltd.	6
Sumitomo Metal Mining	9

Rio Tinto	28
Newmont Mining Corp	19
MMG Mining	5
Mitsubishi Mining	5
GoldFields	8
Goldcorp	9
Glencore	34
Freeport McMoran	15
Codelco	7
BHPbilliton	12
Barrick Gold	17
Areva	6
Antofagasta Minerals	3
African Rainbow Minerals	11
AngloAmerican	26
AngloGold Ashanti	19
Norsk Hydro	2
Lonmin	3

3.4 Data Sources

Most of the secondary data used in the study was gathered through company annual and sustainability reports which were obtained from the company's website, typically, the global company website. A few companies reported mine site specific information separately, either on a regional scale or in accordance with the type of commodity being mined. Some initial observations and difficulties in data collection are recorded as follows:

1. Reports were usually available in PDF formats, however in certain cases interactive online report (html) formats were presented. Interactive reports

- proved to be difficult in analyzing due to frequent and complex use of infographics and in some cases websites being non-responsive.
2. Overlap and inconsistencies in raw material consumption and disposal figures in sustainability and annual reports.
 3. Language barriers. Codelco, a Chile-based copper mining corporation reports sustainability indicators only in Spanish.
 4. Absence of GRI index.
 5. Incomplete reporting. Certain indicators such as EN21 (Total water discharge by quality and destination) were reported on a corporate scale. Without specific mine-site level information, quantifying spills/contamination risk was difficult and in some cases incomplete.

Other data sources included COMPUSTAT, Wharton University of Pennsylvania for financial indicators, AQUASTAT, World Bank Group and World Database on Protected Areas (WDPA), a joint project of International Union for Conservation of Nature (IUCN) and United Nations Environment Program (UNEP) for regional site feature information.

COMPUSTAT was used for the sake of standardization. Although most companies report required financial indicators, COMPUSTAT provided consolidated information in requisite formats for statistical analysis. AQUASTAT was used to gather site level information used to quantify water risk discussed in the next section. WDPA was used to compliment and in some cases validate, whether or not a mine-site was operating in an ecologically sensitive location.

3.5 Water Risk Framework

The water risk assessment framework (Table 3.2) is adapted from Miranda et. al. (2010), Morrison et. Al (2009) and Ceres (2010), discussed in Table 2.2 in the Literature Review Chapter. The risk assessment framework is split in three sub-themes:

- . Area of operation – includes rainfall (average precipitation), ecological sensitivity (protected land) and presence of communal water competition (water stress and reported incidents of operations)
- . Type of commodity/metal mined – includes base or noble metal
- . Type of operation – includes type of mine (open pit or underground) and water disposal conditions (any reported incident of contamination)

Table 3.2: Modified Water Risk Assessment Framework

Nominal Indicators	Average precipitation	Ecologically sensitive	Water stress	Any reported incident of conflict	Open pit or underground mining	Base or noble metal commodity	Any reported incident of water contamination
Yes/High							
No/Low							

As discussed in the literature review, mining is a site-dependent industry. Local water conditions of the area of operations significantly impact the water risk associated with mining mainly because water conditions influence industrial water availability. The Following indicators (Table 3.2) were used to evaluate the water risk in the areas of operation:

1. Average precipitation: This was used to identify if the area of operation is a dry (arid/semi-arid) or water rich region. Rainfall is a primary factor that determines water availability in any watershed. Köppen Climate Classification System (Table 3.3) has been widely used to determine the land type based on temperature and precipitation levels.

Table 3.3: Köppen Climate Classification System (adapted from Kottek et. al. 2006)

Type of climate	Description	Criteria
Equatorial Climate (Tropical)	extend northward and southward from the equator to about 15 to 25° of latitude	$T_{min} \geq +18\text{ }^{\circ}\text{C}$ $P_{min} \geq 60\text{ mm}$ $P_{ann} \geq 25(100-P_{min})$
Arid Climates (Dry)	These climates extend from 20 - 35° North and South of the equator and in large continental regions of the mid-latitudes often surrounded by mountains.	$P_{ann} < 10\text{ mm}$
Warm Temp Climates (Moist Mid-latitude)	Its extent is from 30 to 50° of latitude mainly on the eastern and western borders of most continents.	$-3\text{ }^{\circ}\text{C} < T_{min} < +18\text{ }^{\circ}\text{C}$ $P_{ann} < 40\text{ mm}$
Snow Climate	The location of these climates is pole ward of the C climates.	$T_{min} \leq -3\text{ }^{\circ}\text{C}$ $P_{ann} < 40\text{ mm}$
Polar Climates	Polar climates are found on the northern coastal areas of North America, Europe, Asia, and on the landmasses of Greenland and Antarctica.	$T_{max} < +10\text{ }^{\circ}\text{C}$

Keeping with Köppen Climate Classification System listed in Table 3.3, a score of 750-millimeter rainfall was set as threshold to decide whether a region received high or low rainfall. Typically 750 mm rainfall can range anywhere between equatorial, dry, arid/semi-arid or warm temperature climates listed in the above table.

2. **Ecological Sensitivity:** Ecological sensitivity indicator was used to determine if a mine site is operating within close proximity (50 kilometers) of any ecologically sensitive area that have a recognized protected status. GRI indicators, EN11 (Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas) and EN12 (Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas) were primary data sources, typically reported in corporate sustainability reports. In certain cases, if the name or details of the ecologically sensitive area was not reported in accordance with mine site operation, World Database on Protected Areas (WDPA) was used to cross-reference and validate mine sites in ecologically sensitive areas.

3. **Water Stress:** Water stress is a factor of water availability for human use. It comprises of basic water requirements for human consumption including water for drinking, bathing, cooking and sanitation (Gleick, 2012). The Falkenmark indicator is perhaps the most widely used measure of water stress. It is defined as the fraction of the total annual runoff available for human use. Based on the per capita usage, the water conditions in an area can be categorized as: no stress, stress, scarcity, and absolute scarcity. Table 3.4 provides Falkenmark indicators for water stress based on per capita water availability.

Table 3.4: Falkenmark indicator for water stress (Adapted from Brown and Matlock 2011).

Index (cubic meteres per capita)	Category/Condition
> 1,700	No Stress
1,000 - 1,700	Stress
500 - 1000	Scarcity
< 500	Absolute Scarcity

Keeping with the discussion on water categorization, use and scarcity in Section 2.1, out of 1700 cubic meters 1200 cubic meters is embedded in food produced as a result of productive green water (Swatuk et. al. 2015). Therefore, keeping with Falkenmark indicator listed in Table 3.4, a score of 500 cubic meters per capita was set as threshold to categorize mine site/region as water stress or no stress region.

4. Any Reported Incident of Conflict: Presence of any conflict was reported using exhaustive key-word search using the terms ‘mine-site name’, ‘company name’ and ‘conflict’. Very few conflict incidents were reported in corporate annual or sustainability reports. Amongst the few reported incidents, only a fraction specified mine-site name and other details of conflict.
5. Open pit/Underground mine: As discussed in the Literature Review chapter, water risk, specifically that of water quality, varies significantly between open-pit and underground mines. Contaminants leaching in to groundwater is more likely to occur in underground mines. Water quantity risks are also higher in underground mine sites as they consume relatively more water

than open-pit mines (Miranda et. al. 2009). Keeping with the aforementioned risk assessment, open pit and underground mines were recorded as low or high risk-sites respectively.

6. Base or Noble Metal: Keeping with average water consumption recorded by previous studies (Table 2.1 Literature Review), base and noble/precious metals were recorded as low and high water risk commodity respectively.
7. Any reported incident of contamination: Any reported incident of contamination was recorded using the GRI indicator EN21 (Total water discharge by quality and destination). Not all contamination incidents were accurately recorded due to inconsistencies in reporting. A few companies only reported total volume and quality (grade) of spill, however did not specify mine-site details.

Aforementioned water risk indicators were used to quantify mine-site level water risk based on area of operation, type of commodity and operation. All the indicators were reformulated as nominal indicators discussed later in Section 3.6.

3.6 Dependent and Independent Variables

Table 3.5 provides a list of dependent variables used in the study. Keeping with the research questions water risk indicators described above were classified as drivers that would influence outcomes (Corporate Water Indicators). Table 3.6 lists all the indicators used to assess corporate financial performance. Figure 3.1 is used to explain the relation between sustainability driver /outcome and financial indicators.

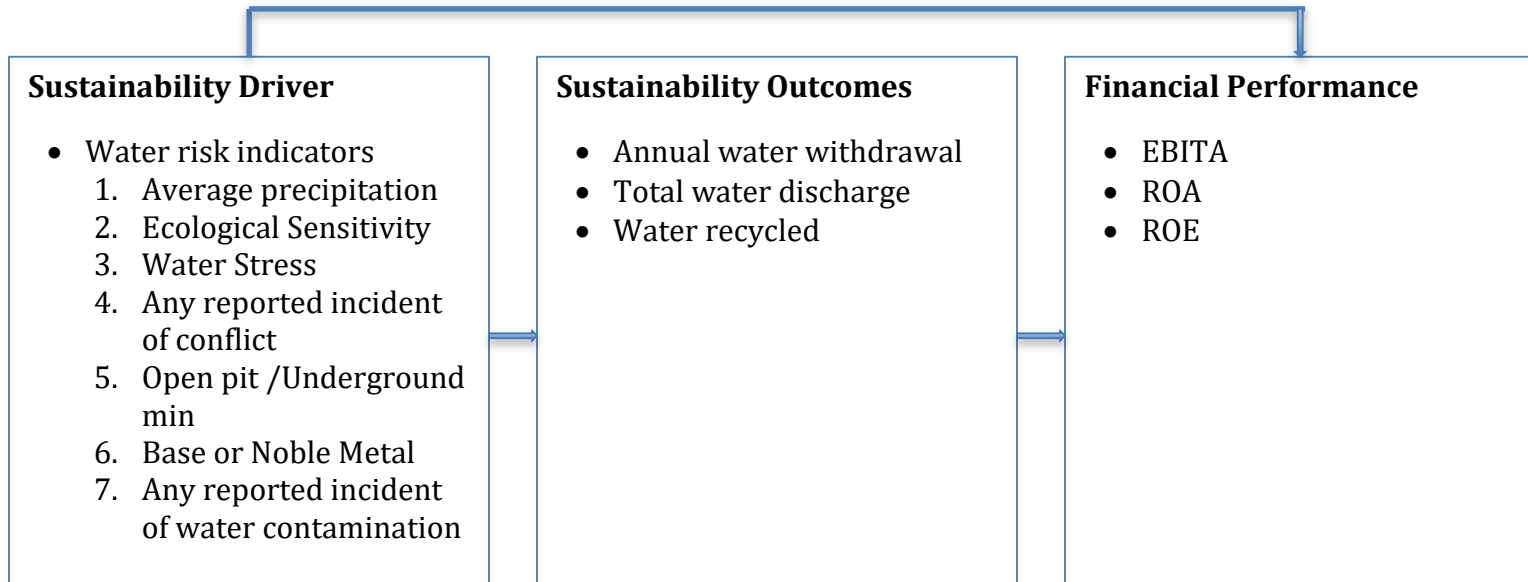


Figure 3.1 The relation between sustainability driver, outcome and financial performance.

Table 3.5: Corporate Water Performance Indicators (Dependent Variables)

Indicator Name	Type	Units
Corporate Water Indicators		
Annual water withdrawal	GRI Indicator: EN8 (total water withdrawal by source)	Million Cubic Meters
Total Water Discharge	GRI Indicator: EN21 (total water discharge by quality and destination)	Million Cubic Meters
Water Recycled	GRI Indicator: EN10 (percentage and total volume of water recycled and reused)	Million Cubic Meters

Table 3.6: Corporate Financial Performance Indicators

Corporate Financial Indicators		
Earnings before interest and tax (EBITA)	Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA)	Million \$USD
Return On Assets (ROA)	Net income / total assets	Million \$USD
Return On Equity (ROE)	Net income / total equity	Million \$USD

Aforementioned corporate water and financial indicators were analyzed separately using various independent variables listed in Table 3.7. Independent variables were used to clearly identify the relationship between sustainability driver and outcome indicators.

Table 3.7: List of independent variables used in the study

Indicator Name	Type	Units
Company name	Dummy variable	
Company headquarters	Control variable	
Company age	Control variable	Number
No of operating sites (globally)	Measure of corporate size	Number
No of active mine sites	Measure of corporate size	Number
Ore Grade (Gold)	Control variable	Oz/ton
Metals mines	Commodity type	
Scale of production	Control variable	Ton and Ounces
Company stake (ownership)	Control variable	Percentage

Finally, corporate financial indicators were used to assess the impact of outcome indicators (corporate water indicators) on the company's financial performance. Keeping with the primary hypothesis of the study, corporate water risk (sustainability driver) would influence corporate water performance (sustainability outcome) that in turn might impact corporate financial performance. Corporate financial indicators (Table 3.6), reflect the company's ability to generate earnings from its investments (operating profitability).

Coding

All the water risk indicators discussed in Section 3.3 were reformulated as nominal indicators, such that they could be answered with either a 'yes/high' or 'no/low'. Presence of the indicator Yes/High corresponded to 1, whereas the absence of the same was recorded as 0. Highest risk score for any given mine site quantified to a total of 7.

All the dependent variables listed in Table 3.5 were incorporated as numeric indicators. Wherever necessary financial values were converted to USD to ensure consistency and fair comparison. This was done using the same conversion rates as the published reports.

Finally, dependent variables consisted of 6 numeric variables and 3 string variables. Metal production was divided on the basis of noble or precious metal and reported in ton/ounces respectively. Finally mine site information was coded on a regional scale. Mine sites were coded into eight distinct regions: Europe, North

America, South America, West Africa, East Africa, South Africa, Australia/Pacific and Asia to draw more cohesive patterns.

3.7 Data Analysis

Data analysis was done using statistical tests. Multiple linear regression models were used to correlate impact on dependent variables, using one or more control variables. Regression models were calculated for the different type of variables involved. These were done to analyze the relationship between sustainability drivers, outcomes and financial indicators, and measure whether the relationships are significant (Anderson 1984).

Chapter 4: Statistical Results

4.1 Introduction

This chapter contains the statistical results of corporate water risk assessment and its impact on water management and financial returns. The focus of the study was to determine corporate water risk based on mine site features and commodities mined, and examine if there is any relationship between water risk, corporate water and financial performance. Keeping with the primary hypothesis of the study, it was assumed that corporate water risk would act like a sustainability driver and lead to better water management (sustainability outcome), that in-turn will influence corporate financial performance. The relationship between water risk, corporate water performance and financial performance was addressed using statistical tests.

Corporate water risk was assessed using seven nominal indicators (listed in methods chapter Table 3.2). Highest risk score for any given mine site was capped at 7. Corporate water risk aggregate was calculated based on all active mine sites per corporation. Water risk analysis was done over regional and corporate scale in order to identify high and low risk regions. For the same purpose, mine sites were categorized into eight distinct regions: Europe, North America, South America, West Africa, East Africa, South Africa, Australia/Pacific and Asia.

Linear regression analyses were conducted using STATA to evaluate impact of water risk on corporate water management and financial performance. Corporate water management (outcome indicators) were assessed using three indicators, namely; (1) annual water consumption, (2) annual water discharge and (3) water recycled. These were analyzed for all 20 companies. Furthermore, to validate impact

of water risk, 120 mine site level data was used to correlate impact of risk on water management, followed by 31 Gold mines.

Finally, financial performance was evaluated using three indicators namely, (1) Earnings Before Interest (EBITA), (2) Return On Assets (ROA) and (3) Return On Equity.

4.2 Corporate Water Risk (Sustainability Driver)

Figure 4.1 represents water risk based on total number of operations, segregated over a regional scale. Figure 4.2 provides a graphical representation of corporate water risk and total number of mine sites. Table 4.1 provides a summary of risk associated with different mined commodities which was calculated using 6 water risk indicators (excluding Type of Commodity).

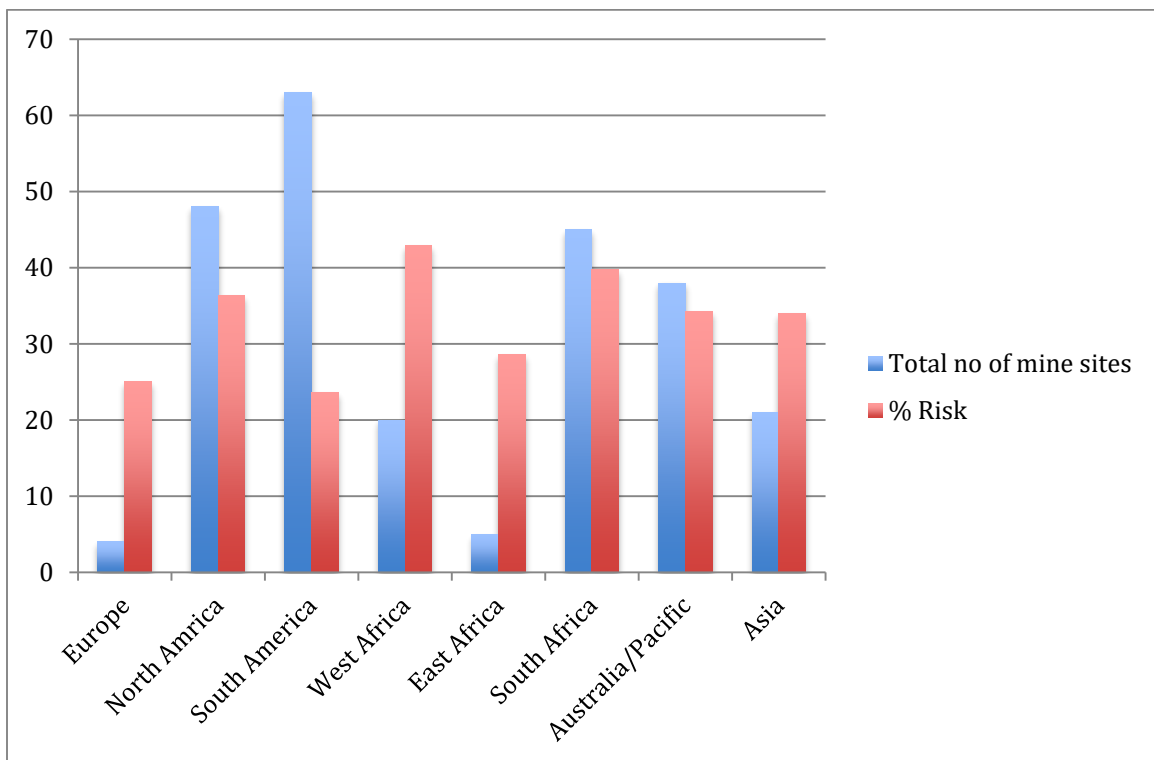


Figure 4.1: Corporate Water Risk based on region of operation

Keeping with Figure 4.1, East, West and South African regions are the most vulnerable in terms of water risk. Maximum mining activity is observed in South America. North America, South Africa and Australia/Pacific are the next biggest producers respectively.

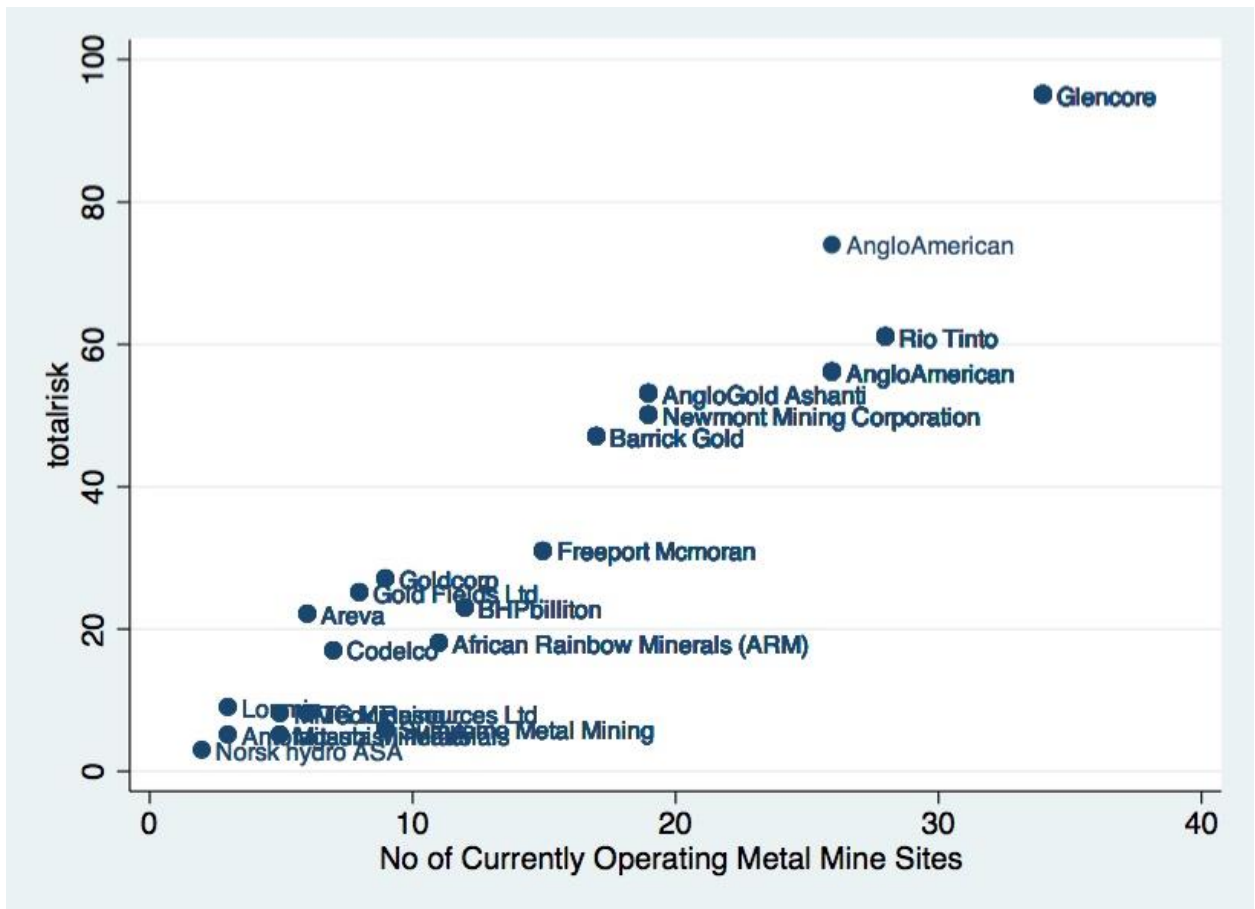


Figure 4.2: Scattered plot - Total risk and number of active mine sites

We can observe a linear rise in water risk in Figure 4.2, consistent with number of active mine sites. Therefore, corporations with a larger global footprint are exposed to higher overall water risk.

Table 4.1: Risk associated with different commodities observed in the sample

Commodity Mined	Total no of operations	Level of risk (%)
Aluminum	12	25
Chrome	1	28.57142857
Copper	61	22.95081967
Gold	76	42.29323308
Iron	13	23.07692308
Manganese	5	25.71428571
Molybdenum	3	33.33333333
Nickel	3	19.04761905
Niobium	1	28.57142857
PGM	34	56.72268908
Silver	4	42.85714286
Uranium	8	50
Zinc	23	37.88819876

Looking at Table 4.1, noble metals had a relatively higher risk (calculated using the number of mines corresponding to a particular commodity), compared to base metals, validating the use of ‘Type of Commodity’ indicator in water risk assessment frameworks.

4.3 Impact on Corporate Water Management (Sustainability Outcome)

A linear regression analysis was used to analyze the relationship between water risk (sustainability driver) and corporate water management (sustainability outcome). Regression modeling was completed separately for all three outcome indicators, using corporate age, headquarters and number of operating sites as control variables. Table 4.2 provides results of linear regression, assessing impact of water risk (independent variable) on annual water consumption (dependent variable), water discharge and recycling respectively.

Table 4.2: Regression analysis of water risk impact on annual water consumption, water discharge and recycled using corporate headquarters, age, number of operations and mine sites as control variables

	Coefficient	t	P>t
Annual Water Consumption			
TotalRisk	-35.36352	-2.45	0.015
Company Name	6.428276	2.03	0.043
Headquarters	-22.291	-6.4	0.001
Founding Year	-3.860728	-7.76	0.001
NoofOperations	-4.331685	-2.96	0.003
NoofCurrentlyOperatingMetal Mines	29.37163	9.59	0.001
Constant	7781.196	7.82	0.001
Annual Water Discharge			
Total Risk	3228.892	2.15	0.033
Company Name	3417.946	9.87	0.001
Headquarters	4963.915	13.9	0.011
Founding Year	-366.4274	-7.71	0.001
No of Operations	259.7924	1.8	0.073
No of Currently Operating Metal Mines	2369.703	7.63	0.001
Constant	587667.8	6.18	0.001
Annual Water Recycled			
TotalRisk	-240.5887	-0.43	0.671
Company name	-1046.283	-6.91	0.001
Headquarters	-391.7481	-2.46	0.016
Founding Year	-148.0885	-5.97	0.001
NoofOperations	119.2313	1.91	0.059
NoofCurrentlyOperatingMetal Mines	-229.6858	-2.09	0.039
Constant	304570.6	6.39	0.001

Significant regression functions were found for all three indicators, annual water consumption ($p < 0.0001$, $r^2 = .62$), annual water discharge ($p < 0.0001$, $r^2 = .84$) and water recycling ($p < 0.0001$, $r^2 = .46$). Since annual water consumption is used as the primary indicator to measure corporate water performance, a variation inflation

diagnostic (VIF) test was conducted with the result showing a 2.32 mean VIF. This indicates that there are no significant impacts of autocorrelation between the independent variables.

These results indicate that water risk does indeed influence corporate water management. Corporate age, location and size also significantly impact water performance. Keeping with Table 4.2, water risk has an inverse relationship with annual water consumption and recycled. The result suggests that corporations that face higher risk have better water performance.

Out of 244 mine sites, 120 reported mine site level water consumption. A regression analysis comparing 120-site level water consumption and risk was conducted to validate the aforementioned results. Table 4.3 provides regression analysis of water risk impact on site level water use using metal production as control variable.

Table 4.3: Regression analysis of water risk impact on mine site level water use

Water Consumption	Coefficient	t	P>t
TotalRisk	1516501	-1.85	0.057
Base Metal Production	1398642	2.31	0.023
Noble Metal Production	1487252	3.56	0.001
Constant	5505934	1.54	0.127

The regression presented in Table 4.3 is significant ($p < 0.0007$), with an explanation of variance of $r^2 = 0.16$, and $VIF = 1.1$. As discussed earlier water risk calculation corresponded to area of operation, type of commodity and type of operation. Results from Table 4.3 indicate that the type of commodity (base or noble

metal) and scale of production has a higher correlation with water performance than the risk associated with area of operation and type of operation.

Similarly 31 gold mines were used to evaluate impact of water risk on site level water consumption using Gold production and ore grade as control variables.

Table 4.4: Regression analysis of water risk impact on gold mine site level water use using metal production and ore grade as control variables

Water Consumption	Coefficient	t	P>t
TotalRisk	-519973.9	-0.44	0.661
Gold Production	-.0025054	0.001	0.999
OreGrade	4131404	0.37	0.714
Constant	5583938	1.78	0.086

Regression functions for Table 4.4 include $p < 0.95$, with an explanation of variance of $r^2 = .01$. The results indicate an insignificant relationship between water risk, production scale and ore grade and water performance.

Over all tables 4.3 and 4.4 indicate similar (inverse) relationship between water risk and water consumption as aforementioned in Table 4.2. However the significance of the relationship depends on the type of commodity (base or noble). Figure 4.3 provides a graphical representation of water risk and annual water withdrawal on a company level.

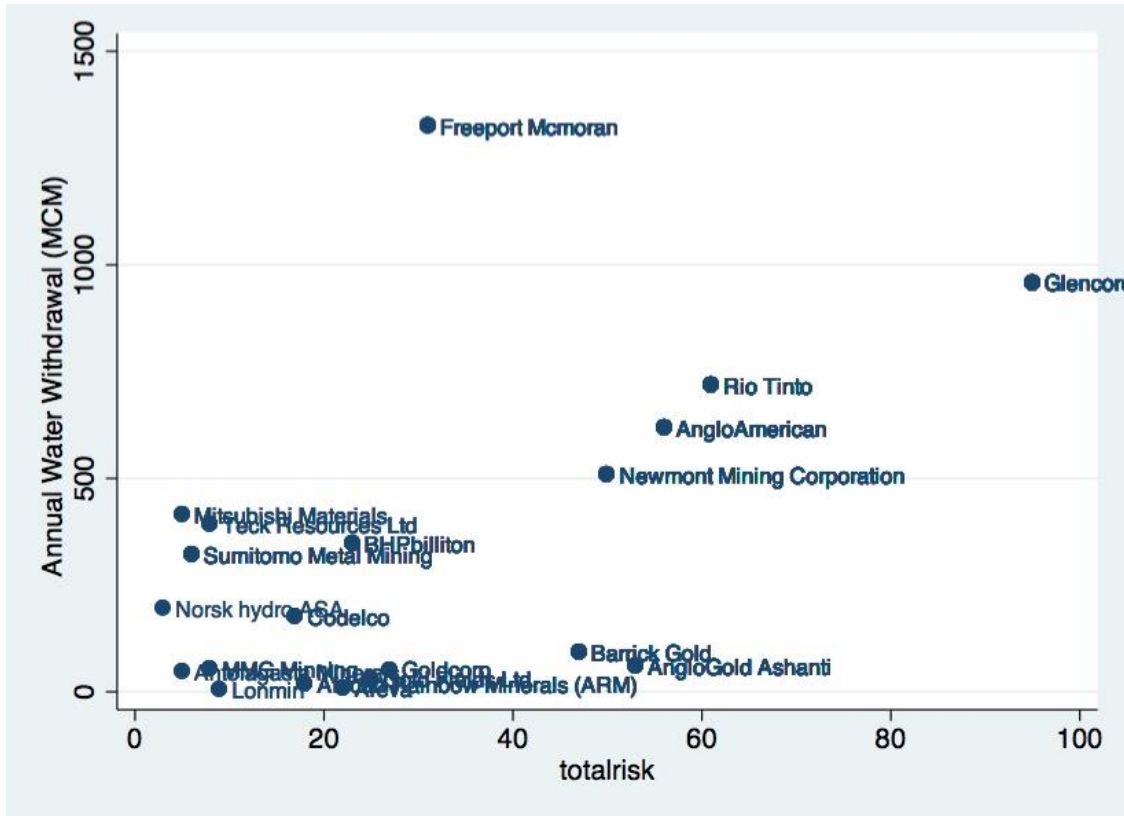


Figure 4.3: Scattered plot – annual water withdrawal and total risk.

Keeping with figure 4.3, water withdrawal peaks for companies facing lower water risk and is consistently low for companies facing higher risk. Depending on the scale of production and global footprint a few companies stand out namely Freeport McMoran and Glencore.

4.4 Impact on Corporate Financial Performance

The second hypothesis included evaluating the impact on corporate financial performance using the aforementioned (sustainability outcome) water performance indicators. Table 4.5 provides regression analyses of water management (annual water consumption, discharge and recycling) impact on corporate financial

performance (Earnings Before Interest [EBITA], Return On Assets [ROA] and Return On Equity [ROE]) using corporate mine stake holding as a control variable.

Table 4.5: Regression analysis of corporate water management impact on EBITA, ROA and ROE

Earnings Before Interest	Coefficient	t	P>t
EBITA			
Annual Water Withdrawal	8.506161	7.95	0.001
Total Water Discharge	16.24433	7.31	0.001
Water Recycled	-12.03693	-9.48	0.001
Ownership	4.546821	0.94	0.351
Constant	-1460.874	-2.76	0.008
ROA			
AnnualWaterWithdrawal	.0026522	30.15	0.001
TotalWaterDischarge	.0041573	22.75	0.001
WaterRecycled	-.0018937	-18.14	0.001
Ownership	.0003739	0.94	0.351
Constant	-1.200743	-27.63	0.001
ROE			
AnnualWaterWithdrawal	-.0008893	-1.13	0.264
TotalWaterDischarge	-.0070428	-4.31	0.001
WaterRecycled	.0076689	8.22	0.001
Ownership	-.0033435	-0.94	0.351
Constant	-.136103	-0.35	0.728

Results derived significant regression functions for all three financial indicators; EBITA ($p < 0.0001$, $r^2 = .76$), ROA ($p < 0.0001$, $r^2 = .99$) and ROE ($p < 0.0001$, $r^2 = .96$). Variation inflation diagnostic test results indicated a higher autocorrelation of 76 percent.

Results indicate a positive relationship between EBITA, ROA and annual water consumption /discharge, and an inverse relation with ROE. Indicating that higher water consumption leads to higher corporate earnings.

Water recycling on the contrary, had a negative influence on EBITA/ROA and positive a relation with ROE indicating loose in revenue. The quantity of metal production being a key factor that determines water consumption, these results can be attributed to income generated from metal production. More water consumed implies more metal production that reflects in higher revenue.

To analyze whether water risk has any impact on corporate financial performance, a regression analysis on EBITA using corporate annual water consumption and water risk was conducted. Results are documented in Table 4.6.

Table 4.6: Regression of corporate water consumption and water risk on corporate financial performance (EBITA/ROA/ROE)

	Coefficient	t	P>t
EBITA			
Annual Water Withdrawal	0.0031812	10.5	0.001
Total risk	-0.0012737	-0.36	0.72
Constant	6.821241	54.41	0.001
ROA			
Annual Water Withdrawal	0.0000674	0.06	0.95
Total risk	-0.036298	-2.36	0.019
Constant	2.52545	3.73	0.001
ROE			
Annual Water Withdrawal	0.0013095	0.45	0.65
Total risk	-0.1199066	-2.88	0.004
Constant	7.831975	4.28	0.001

Regression functions observed for EBITA, ($p < 0.0001$, $r^2 = .54$), ROA ($p < 0.02$, $r^2 = .03$) and ROE, ($p < 0.006$, $r^2 = .04$). The relationship between annual water consumption and corporate earning (EBITA) is similar to the regression results presented in Table 4.5. Although water risk has an inverse relationship with corporate earnings

(EBITA), the relationship is not significant, indicating that more water consumption drives up metal production and leads to more revenue even in high water risk scenarios.

Figure 4.4 provides a graphical representation of corporate earnings mapped over water risk.



Figure 4.4: Scattered plot -EBITA and total risk

Keeping with results presented in Table 4.6, there are no significant patterns between corporate earnings and total risk represented in Figure 4.4.

Chapter 5: Discussion

5.1 Introduction

Water is a key requirement for mining. As aforementioned, water consumption primarily depends on the scale of production, ore grade, technology involved and the commodity being mined (Miranda, Sauer and Shinde 2010). Keeping with the growing water-related trends in mining discussed in Section 3.4, such as rising demand for mined products, growing mining activities in water-scarce regions of the world, globally declining ore grade and climate change; water risk associated with mining is increasing manifolds. The focus of this thesis was to quantify water risk associated with mining based on mine site features. Furthermore, analyze how companies are managing risk guided by concepts such as corporate water responsibility, corporate social responsibility (CSR) and environment management systems (EMS). This was done using the following research questions:

1. What is the relationship between water risk and corporate water performance?
2. What is the relation between water performance (non-financial) and financial performance of companies?

Overall various significant statistical correlations were found. These have been listed in the previous chapter (Results). These results enrich the field of corporate water responsibility and provide practical results from a mining perspective on limitations in quantifying benefits (financial) of CSR and EMS.

This chapter contains the discussions of quantitative results and describes contribution to theoretical frameworks.

5.2 Water Risk

As discussed in the Methods Chapter (Section 3.3), water risk was calculated using seven nominal indicators based on the area of operation (mine site features), type of commodity mined and type of operation. Water risk varied across companies and region. Keeping with Figure 4.1 presented in the Results chapter, companies with a larger global footprint were exposed to higher risk. East, West and South African regions were amongst the most vulnerable regions in terms of water risk.

West and East Africa were also amongst the regions with highest reported incidents of social conflicts. In some cases these conflicts resulted in communal violence, terrorism and social unrest (ICMM 2015). 98 per cent of the mines in these regions were involved with precious metal mining namely Gold and Uranium. Rio Tinto, Newmont Mining Corporation, Gold Fields, Areva, AngloGold Ashanti and Barrick Gold are amongst the few corporations with significant stake in the region.

South America accounted for the highest number of mines and relatively low water risk. This can be attributed to high rainfall, low water stress, negligible reported incidents of water contaminations and very few ecologically sensitive areas in the vicinity of the mines. The region however faces high risk due to social conflict

In contrast, mines in Australia reported least incidents of conflict however a much higher risk associated with limited rainfall and ecological sensitivity. Australia

also has one of the most robust mining associations such as Mineral Council of Australia (MCA) and Australian Mines and Metals Association (AMMA). MCA is regarded as one of the most technologically advanced, socially and environmentally progressive mining conglomerate (Miranda, Sauer and Shinde 2010) with a detailed water accounting framework (MCA 2012). Also a well-balanced extraction of base (48 per cent) and noble (52 per cent) metals was observed in Australia. Compared to other regions such as South Africa, West Africa and South America that accounted for more than 60 per cent precious metal mining.

Aforementioned regional variance in water performance to a significant extent can be attributed to a combination of two key factors: (1) perceived water risk, (2) regulating and law enforcement agencies. Governments have a responsibility to ensure sufficient water is being allocated to sustain human requirements, and anticipate future targets to ensure adequate measures are in place to improvement water use efficiency (Ruggie 2008; 2009). Keeping with the hypothesis of the study, perceived water risk is a compelling sustainability driver (Miranda, Sauer and Shinde 2010; Mining, Minerals and Sustainable Development 2002). Compared to rest of the developed regions that typically have stringent regulations and effective monitoring system (WWAP 2012; WBCSD 2006), Australia being a mostly arid/dry region also faces water shortage. Reaffirming the importance of collaboration to operationalize corporate water responsibility.

5.3 Examples of Water Risk

Keeping with the various types of water risk discussed in Section 1.2 (literature review), a few companies reported risks that can be categorized as examples of physical, reputational and regulatory risks that have direct impact on corporate financial performance.

Physical Risk – Following acute water shortage in semi-arid and dry parts of Chile, AngloAmerican invested more than \$100 millions on a desalination plant with an expected life span of 20 years to reduce dependence on Copiapó basin, a primary source of water for Mantoverde operation, company's flagship mine site (AngloAmerican 2014).

Reputational Risk – A community strike in Marikana, South Africa, Platinum mine owned by Lonmin resulted in production loss of as high as 47 per cent (6.4 million tons) in 2013-14 (Lonmin 2014).

Regulatory Risk – Operations in Los Bronces, a mine operated and partially owned by AngloAmerican and Rio Tinto was fined for non-compliant remedial activity following a waste dump acid-drainage incident in 2013. Failure in addressing outstanding issues may result in risk of permanent closure (AngloAmerican 2014).

Aforementioned incidents re-affirmed water risks involved in mining and its impact on corporate financial performance. Aforementioned corporations also stand out in Figure 4.4 with uneven water consumption and water risk.

5.4 Benefits of Corporate Social Responsibility and Environment Management System on Water Risk

Keeping with the Corporate Water Responsibility discussion in Section 1.3, there is a fine line between corporate and government responsibility when it comes to water management. Corporate activities that may impact or deprive local community of water resources are grounds for corporate liabilities (Gleick 2012). Corporations that documented and specifically addressed social issues in their annual and sustainability reports scored relatively lower risk. To name one amongst a few, Barrick Gold, a Gold mining corporation with 17 active mine site scored relatively lower risk compared to other similar scale Gold mining corporations such as AngloGold Ashanti, Goldcorp and GoldFields. The company actively reports impact on local communities and CSR initiatives focusing on addressing these issues. For instance, in Pueblo Viejo, Dominican Republic, a small number of communities near the mine have historically faced difficulties accessing clean water due to drought conditions. Barrick has been supplying tanks and bottled water to these communities since mid-2012 as a short-term solution. In 2014, the mine, with the support of an external consultant, determined that the best solution would be to construct four groundwater wells to be integrated into the current water supply system (Barrick Gold 2014). Examples such as aforementioned were documented while mapping water risk disclosure in corporate reports.

Keeping with the previous discussion on regional water risk, Australia one of the most water scarce regions also hosts relatively more mines. The region is also the highest producer of base metals and second highest producer of precious metal

closely following South Africa. It has the lowest reported incidents of social conflicts. This perhaps in some way can be attributed to the stringent mining regulations that promote implementation of Environmental Management System (EMS). Minerals Council of Australia (MCA) follows an integrated materials management approach based on the principle of life-cycle analysis and industrial ecology. The EMS system is available to local governments in-charge of monitoring and corporations that are a part of MCA (MCA 2012).

5.5 Impact on Corporate Water Management

The study was based on the premises that exposure to water risk (sustainability driver) would propel companies to maintain a better water portfolio (outcome), that in-turn will influence corporate financial performance. The relationship between sustainability driver and outcome indicators was analyzed using linear regression models presented in Table 4.2.

Keeping with the results discussed in previous chapter, companies facing high risk judiciously manage water requirements and focus more on recycling and reusing available water. However, the same cannot be said for impact of water risk on water discharge. There is a scope of error since only 17 out of 20 companies reported annual water discharge. The positive relationship can be attributed to dependence of water discharge practices on proximity to shared water resource/source, infrastructure and legal requirements (Mining, Minerals and Sustainable Development 2002; Goodland 2012; Mudd 2010). Typically water is held in designated tailing ponds before releasing into the environment (Mudd 2010;

Mining, Minerals and Sustainable Development 2002) and most of the water risk indicators used in the study focus more on water availability in a watershed. Risk indicators specifically focusing on water quality and contamination risks might provide better correlation.

Furthermore, the relationship between corporate water consumption and water risk is not significant compared to the type of commodity. As observed in Tables 4.3 and 4.4, water risk continues to have an inverse relationship with water consumption however the relationship is less significant compared to metal production, type and ore grade. This is consistent with the findings by Norgate and Lovel (2004) and Mudd (2007) discussed in the Literature Review (Section 2.3). Both the studies focused on quantifying water consumption for different metal types, and concluded that noble metals tend to consume disproportionately more water in general. Furthermore, noble metals such as Gold are economically viable to extract even in low concentration (ore grade) and no significant correlations were found between Gold ore grade and water consumption. This was attributed it to the varying complexity of gold mines and metallurgical differences between ores, the type and degree of processing (Mudd 2007). The findings are consistent with results described in Table 4.4. Economic value of the metal is the primary factor that determines production (Norgate and Lovel 2004). Overall companies are adept in quantifying water risk and tend to regulate consumption well for base metals, however the same cannot be said for precious metals.

Corporate age also had an inverse relationship with all three corporate water performance indicators namely, annual water withdrawal, discharge and recycled. Indicating that older companies tend to perform better than their newer counterparts. This can be attributed to experience, better EMS and available infrastructure/capital to efficiently manage water. As discussed in the literature review Section 2.1, effectiveness of EMS depends on the age of management system and available resources. Financial constraints particularly in a capital-intensive sector such as mining are sometimes barriers towards effective implementation and adoption (Steven 2003; Baxter 2011).

Number of active mine sites, a measure of corporate size has a linear relation with annual water withdrawal and discharge. This can be attributed to economies of scale; more operations indicate more mining activity, a key factor that determines water consumption.

5.6 Impact on Corporate Financial Management

The second research question 'What is the relation between water performance (non-financial) and financial performance of companies?' was analyzed separately using corporate financial data and water performance indicators. Based on the second phase of the hypothesis that better corporate water performance in terms of lower consumption, lower discharge and higher water reuse would reflect better financial performance. It was hypothesized that these financial benefits would be resultant of lower cost associated with water pumping,

treatment and discharge linked to lower overall water withdrawal (Hilson and Murck 2000; Hilson and Nayee 2002).

Regression analysis of corporate water performance on Earning Before Interest and Tax (EBITA) and Return On Assets (ROA) yielded similar results. Annual water withdrawal and total discharge had positive relationship to EBITA and ROA, although a negative relationship was observed for water recycling. These results indicate that higher water consumption and discharge relate to higher income generated from metal production. Furthermore, corporations loose revenue in water recycling and reuse. Indicating that it is relatively cheaper to use fresh water than treated water for mining operations. These results to some extent correlate to the growing investment towards alternate water sources such as desalination plants by larger corporations such as AngloAmerican in Chile, Glencore in USA and Rio Tinto in Nambia (AngloAmerican 2014; Glencore 2014; RioTinto 2014).

Regression analysis on Return On Equity (ROE) provided contrasting results to EBITA and ROA. ROE has an inverse relationship with water withdrawal and discharge and a positive relationship with water recycled. One possible explanation for this could be if the company is financing more through debt.

Finally, a regression analysis to evaluate the impact of annual water withdrawal and water risk was conducted separately on corporate financial performance (EBITA/ROA/ROE) to analyze cumulative effect of risk and water consumption on corporate financial performance. The results have been presented

in Table 4.6. The results indicated a significant relationship between water consumption and corporate earnings (EBITA). Water risk consistently had an inverse relationship with all three financial indicators with the highest probability of correlation with ROE. From the results presented in Table 4.6, it can be concluded that there is not a significant relationship with corporate sustainability (non-financial) performance and financial performance.

These results are similar to a previous study conducted by Weber & Banks (2012), analyzing corporate sustainability assessment in financing the extractive sector. The study compared 262 companies and concluded that there was no significant correlation between corporate sustainability and financial performance (Weber and Banks 2012).

From a water perspective, a non-significant correlation between water performance and financial performance can be attributed to low water tariff that does not take into account various environmental and social (externalities) costs. Typically extractive industries operate in remote locations with bulk tariff allocation and often have unrestricted access to water sources/supply (Gleick 1993; Gleick 2014; Lambooy 2010; Martinez 2015). Water globally needs to be viewed as an economic good and water tariff needs to be modified extensively to account for full (environmental and social) costs. Water as an economic good is a relatively new concept that needs to be better explained and addressed in corporate water responsibility.

Chapter 6: Conclusion

6.1 Contribution of the research

6.1.1 Contribution to theory

The study explored impact of water risk as a sustainability driver on corporate water performance guided by the principles of corporate water responsibility. The study explored the gaps in sustainability concepts of Corporate Social Responsibility and Environment Management Systems in identifying and tracking financial implication on corporate performance(Weber 2007; Steven 2003; Peloza 2009; Kevin 2004).

Based on the results, there is a greater need to collaborate with various stakeholders and internalize environmental and social costs associated with business operations. Particularly from a water perspective, there is a need to re-evaluate water tariff that ensure equity, efficiency and ecological integrity (WWAP 2012).

Corporate water responsibility is a high priority for mining industry (Hilson and Nayee 2006; Goodland 2012) especially in the face of growing water requirement, water scarcity, increased demand for mined products, falling ore grade and climate change (Miranda, Sauer and Shinde 2010; WWAP 2012). CSR and EMS are pivotal in ensuring industries meet sustainability goals (Hamann 2003; Goodland 2012; Hilson and Murck 2000). However, financial limitations are a critical constraint and limits adoption and development of these concepts (Hilson

and Nayee 2006; Steven 2003). Long-term financial benefits need to be tracked to promote investor confidence and re-assure benefits of sustainable operations.

Research has found that a combined effect of inadequate/low water cost and gaps in sustainability concepts (CSR and EMS) to track financial impact might be a deterrent in realizing corporate water responsibility and effectively manage limited water resources.

6.1.2 Contribution to practice

The study found that the mining industry recognizes water risks and extent of risk exposure influences corporate water performance. Risk assessment frameworks and results need to be disclosed to allow comparison and identify best practices. Specifically information on site water availability, details about the type of commodity mined and technology employed to extract resources.

Mining corporations and associations need to move towards a common reporting methodology in order to create better water metrics.

6.2 Limitations

Following are some of the key limitations of the study:

1. Data gaps – certain indicators such as corporate water discharge was not consistently reported. Water contamination (spill) indicators were not consistently reported either. Furthermore, in most cases these indicators were documented on a corporate scale, making them impractical for use.

2. Water risk assessment framework used in the study primarily focused on water availability. Few indicators were used to analyze water quality concerns, a major issue related to mining.

6.3 Future Recommendations

The study found a positive correlation between water risk and corporate water performance, however the results were not significant for precious metals. As aforementioned this could be due to metallurgical differences between ores, the type and technology of processing. Further analysis focusing on a specific commodity that also looks into technology/metallurgical processes involved could yield more accurate results.

Furthermore, the study did not find a significant correlation between water risk and corporate financial performance. As discussed earlier, this could be due to incomplete cost of water. Future studies that focus on internalizing environmental and social costs associated with mine water use could perhaps shed some light on the impact of mining and financial impact of sustainable water management.

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Appendix 1

Key Concepts and Definitions

This section comprises of some key mining concepts and definitions. Terms used in this section are imperative to understand indicators (discussed in the methods chapter) used to assess water risk and water management practices.

Mine Site Water Balance / Account:It accounts for all water sources, sinks and storage facilities within a mine site. Generally mine site water balance fall under three categories: (1) positive, (2) neutral and (3) negative. A positive water balance means that a site has excess water and therefore needs to discharge water in the surrounding environment. Mine sites with a net positive water balances are commonly mandated by law to treat their water discharge. Negative water balance accounts for water shortage and the site must withdraw water from the surrounding environment. A neutral water balance indicates that a site's water sources and sinks are in balance. Neutral water balance is an ideal condition for any mine site, however it is uncommon and temporary due to variations in water availability depending on seasonal changes.

Mine Concentrate:Mine concentrate refers to any valuable product mined and transported off the mine site. Typically there is minimal water in mine concentrate since most is dewatered before transportation.

Dewatering:Dewatering refers to the practice of pumping out ground water from the surface of a mine site. It is generally done to prevent flooding and/or improve

ground stability. Water pumped is either discharged into the surrounding environment or diverted for mine use.

Mine: Mine is excavation in the Earth used to extract ore. Typically there are two types of mines, open and underground. Open mine is an excavation on the surface whereas underground mine refers to an excavation under the earth's surface.

Ore: An ore is a type of rock that contains sufficient minerals with important elements including metals that can be economically extracted from the rock. The amount of valuable mineral in a rock is defined as ore grade, and is generally referred in percentage.

Recycled Water: Water that is treated from one or more source prior to use.

Reused Water: Water that is reused after one or more process without undergoing any treatment.

Reclaim Water: Water diverted from the mines tailing ponds. Reclaimed water is typically treated using settling and ultraviolet rays. Reclaimed water is also a type of recycled water.

Run of Mine (ROM): ROM refers to the ore as it comes from the mine. It has not been screened, crushed or processed.

Tailing: Tailing refers to a storage facility at a mine site for any remaining waste product after the mine concentrate has been removed is stored and managed. Excess water from tailing is diverted, treated and sometimes re-used within the mine (Reclaimed water).

Waste Rock:Waste rock refers to rocks excavated that do not contain sufficient minerals from an economic standpoint. Waste rock is typically placed in a large storage referred to as waste rock dump.

Slag:Slag refers to the waste metal oxides that are left behind after valuable minerals have been extracted from the ore.

Water Consumption:Water consumption is the difference between all water withdrawn and the sum of water discharged and stored in a mine site. Zero discharge refers to the practice of maintaining a balance between water consumption and mine sinks and storage facility.

Water Discharge:Water discharge refers to excess water (water not lost and can't be stored) that is discharged into the surrounding water from a mine site. This does not include evaporation.

Water Source:Water source is a supply point for any water inflow in a mine site. Typically water source consists of precipitation, ground water (dewatering), moisture from ore and external sources such as municipalities.

Mine Reserve Life:Reserve life refers to the duration of economic viability of continuing ore extraction at any given mine site. It is typically calculated using geological indicators, ore grade and global demand for mineral.

The above terms and definitions correspond to those used in the industry, government standards and academic research. Definitions have been adapted from Habashi (1997), *Handbook of Extractive Metallurgy, Volume 2*.

Appendix 2

ICMM 10 Principles

1. Implement and maintain ethical business practices and sound systems of corporate governance.
2. Integrate sustainable development considerations within the corporate decision-making process.
3. Uphold fundamental human rights and respect cultures, customs and values in dealings with employees and others who are affected mining activities.
4. Implement risk management strategies based on valid data and sound science.
5. Seek continual improvement of health and safety performance.
6. Seek continual improvement of environmental performance.
7. Contribute to conservation of biodiversity and integrated approaches to land use planning.
8. Facilitate and encourage responsible product design, use, re-use, recycling and disposal of our products.
9. Contribute to the social, economic and institutional development of the communities in areas of operation.
10. Implement effective and transparent engagement, communication and independently verified reporting arrangements with stakeholders (ICMM 2015).